Summative Evaluation of the Impact of *Secrets of the Universe* Giant Screen Film and Related Small Screen Videos on Middle School Students

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Table of Contents

Executive summary

With funding from the National Science Foundation, *Secrets of the Universe* (SOTU) is a multimedia project that has at its core a 40-minute 3D giant screen film directed by a collaboration of K2 Communications Inc., The Stephen Low Company, and University of California Davis Department of Physics. The film gives viewers an inside look at the largest scientific instrument ever built, the Large Hadron Collider (LHC), while introducing past and present scientists who have worked to understand the fundamental nature of the universe. SOTU is designed for general audiences who watch the film at local science centers and specialty theaters, and also for middle school students who watch the film as part of a museum field trip. To support and extend the impact of the film for these audiences, the project features an educational website with a variety of resources, including online videos of science content and characters from the film.

The independent evaluation team from Knight Williams Inc. conducted a summative evaluation of the SOTU project in two phases. Phase 1 addressed the impact on 5th to 8th graders of viewing online seven minutes of small screen videos, focused either on science content or science characters, prior to viewing on the next day the 40-minute SOTU giant screen film. The evaluation assessed the perceived impact of the pre-film types on the film experience, the appeal of the film itself, and the impact of both media on student learning and interest regarding science and scientists, with additional analyses by gender and by younger and older grade levels. Through conversation groups with middle school girls, Phase 2 further explored girls' experience with the science characters in the pre-film videos and film, focusing on the impact of the science characters on the girls' thoughts of scientists and their opinions of the effectiveness of the science characters as role models in encouraging their interest in science.

Phase 1 employed a two-group posttest-only randomized design. Middle school classes were randomly assigned, within seven schools, to one of two conditions: watching either pre-film science content videos or science character videos in school. Within one to two days, all 170 students then watched the giant screen SOTU film at the Museum of Science and Curiosity (MOSAC) in Sacramento, CA, as part of a school field trip. They then completed an online post-viewing survey at school within one to two days of the film viewing. An additional group of 20 6th to 8th grade girls from a variety of Sacramento-area schools participated in Phase 1 by watching the pre-film science character videos at their home and then visiting MOSAC within one to days to view the film and complete the post-viewing survey. Subsequently, the girls participated in small conversation groups at MOSAC as Phase 2 of the evaluation to further explore their experience with the SOTU science characters.

Of the 190 Phase 1 students, 51% viewed the pre-film science content videos and 49% viewed the pre-film science character videos. The two independent groups did not differ significantly with respect to gender, age, and minority/non-minority distributions. However, due to an uneven distribution of which grades viewed which pre-film videos, 5th, 6th, and 7th graders were combined into a younger grade level group and compared with the older 8th grade level in analyses.

To address the evaluation questions about video group, gender, and grade level differences, the statistics of two-sample two-tailed *t*-tests were applied to quantitative data and Fisher exact tests applied to qualitative data gathered from the Phase 1 surveys. Content analyses were performed on the qualitative data generated in the open-ended survey questions and gathered in the Phase 2 conversation groups. Key findings from the summative evaluation are presented below.

- **Impact of pre-film videos on students' film experience.** More than two-thirds of the students thought the videos had a positive effect on their experience of the SOTU film, with the largest groups explaining that the videos increased their understanding of the topics presented in the film or were a good preview for the film. Those who watched the science content videos, which introduced the subject of LHC research, were significantly more likely to say that the videos increased their understanding of the film's topics (for example, the LHC, how it works, and the research being done there) compared with those who watched science character videos.

  When asked to explain what about the videos stood out for them, half of the students commented on LHC technology, such as the Collider, its size and location, and how it works, and two-fifths pointed to aspects of LHC research on atoms, protons, and collisions. Those who reported about LHC technology or research were significantly more likely to have watched the content videos than the character videos. This finding points to the positive impact of these videos on students' experience of SOTU science content.

  One-third of students noted that the scientists stood out for them in their experience of their pre-film videos. These students were significantly more likely to have watched the character videos than the content videos. Similar to the above, this finding points to the positive impact of these videos on students' experience of the SOTU scientist character content.

- **Appeal of the *Secrets of the Universe* film.** On average, students somewhat liked the film, with the younger grade level of 5th, 6th, and 7th graders liking the film significantly more than the older 8th grade level. On average, students also thought the film was somewhat clear, found both the presentation of science content and scientists somewhat interesting, and found the level of science somewhat too advanced. The younger grade level rated both the presentation of science content and scientists as significantly more interesting and the level of science significantly more advanced compared with the older 8th grade level. Even though the advanced physics content of the film is not typically addressed in middle school science curriculum, these findings indicate that the project team will likely want to continue outreach to younger middle school students and school groups, and as part of this outreach suggest the use of pre-film resources to help prepare them for the science content.

  When asked what they liked most about the film, between one-quarter and one-half of the students pointed to an aspect of the filmmaking (most often noting the visuals), the scientists, the informative quality of the film, and the experience of watching the film in a dome theater. Girls were significantly more likely than boys to report liking an aspect of filmmaking, and the younger grade level was significantly more likely than the 8th graders to report liking the scientists.

  About a fifth each of students most liked the film's focus on LHC technology or LHC research. Those who watched the content videos were significantly more likely to report that what they liked about the film was LHC technology or LHC research, compared with those who watched the character videos. Girls were significantly less likely than boys to report liking the focus on LHC technology or LHC research.

  When asked what they did not like about the film, two-fifths of students pointed to an aspect of their theater experience, for example finding the seating uncomfortable, possibly because they were seated toward the front of the dome theater and had to lean their heads back to view

aspects of the film. A quarter said the film was confusing or not well explained, and about a fifth each described the film as too long or boring.

- **Combined impact of pre-film videos and film on learning about and interest in science.** On average, students thought that seeing the SOTU videos and film somewhat increased their knowledge about science and somewhat increased their interest in science. The younger grade level of 5th, 6th, and 7th graders thought their knowledge of and interest in science both increased significantly more than the 8th grade level's self-assessments.

  When asked to share what they had learned about science from the videos and film, two-fifths of the students described having learned about scientists or their discoveries, with girls being significantly more likely than boys to mention this category of learning. Two-fifths also reported that they learned about the Collider, with boys and those who watched the content videos being significantly more likely to report this category of learning compared with girls and those who watched the character videos, respectively. Finally, two-fifths of the students thought they had learned about atoms, protons, or particle collisions, and one-fifth thought they had learned about astrophysics or astronomy.

  These same four topics – scientists and their discoveries; the Collider; atoms, protons, or particle collisions; and astrophysics or astronomy – were each cited by one-fifth to two-fifths of students as things about the SOTU videos and film that affected their interest in science. The film's focus on atoms, protons, or particle collisions was significantly more often given by the younger grade level compared with the 8th grade level.

- **Combined impact of pre-film videos and film on learning about and interest in scientists.** On average, students thought that seeing the videos and film somewhat increased their knowledge about scientists and somewhat increased their interest in scientists. The younger grade level of 5th, 6th, and 7th graders thought their knowledge of and interest in scientists both increased significantly more than the 8th grade level's self-assessments.

  When asked to share what they had learned about scientists from the videos and film, two-fifths of the students thought they had learned about the work being done by present-day scientists, less than a third thought they had learned about the characteristics of scientists (for example describing them as smart, hardworking, or passionate), and more than a quarter said they had learned about scientists of the past or their discoveries.

  These same three topics – learning about the work being done by present-day scientists, the characteristics of scientists, and scientists of the past and their discoveries – were each cited by one-fifth to one-third of students as things about the SOTU videos and film that affected their interest in scientists. The film's focus on scientists of the past and their discoveries was significantly more often given by girls than boys, and by the younger grade level compared to the 8th graders. The largest group, a third of students, said nothing affected their interest in scientists, with significantly more 8th graders giving this response than the younger grade level.

- **Further exploration of girls' experience with the SOTU science characters.** Among the 20 girls who participated in the Phase 2 conversation groups, three-quarters indicated that the SOTU videos and film positively changed their thoughts about scientists, with a few of these

girls explaining that their thoughts changed in both positive and negative ways. Additionally, half of the girls said they could see themselves in one or more of the scientist roles pictured on screen, typically as a graduate student, and most often as Dr. Santona Tuli.

When girls were asked what characteristics they thought would make a role model most effective in encouraging their interest in science, half said having a strong work ethic/success, two-fifths said being an influencer/inspirer, and one-third said having passion. Considering these and other science role model characteristics the girls discussed in their conversation groups, more than four-fifths of the girls identified one or more of the scientists in the videos and/or film as effective in encouraging their interest in science. Just over half of the girls pointed to Dr. Santona Tuli and just under half pointed to the historical scientists in the film, with other scientists being mentioned less frequently.

Finally, not quite half the girls shared three suggestions for changing or adding to the portrayal of women scientists in the SOTU videos and film, including: the addition of more in-depth knowledge about the women scientists' backgrounds and experiences leading to their careers; an increase in the number of women represented in the videos; and more visual representations of women at work.

Looking across the full group findings, gender, grade level, and video type viewed all showed significant differences in areas assessed in Phase 1 of the evaluation, as further detailed in the discussion section on page 55. Compared with the boys, the girls showed significant differences in multiple areas, including what they liked about the film, areas of learning from the videos and film, and the impact of the SOTU videos and film on their interest in scientists. Grade level also had a significant impact in multiple areas, including the appeal of the film and what they liked most about it, learning from the videos and film, and interest in science and scientists. Video type viewed prior to watching the film showed significant differences in what stood out about the videos, how the videos affected students' film experience, what students liked about the film, and learning about science and scientists.

Finally, as described in the discussion section, the findings in this report point to three main suggestions the project team may want to address while the film is still showing in theaters: creating or pointing educators to additional supplemental materials that highlight the work of scientists past and present, adding a glossary and/or Frequently Asked Questions section to the SOTU website, and packaging the science content and scientist character videos into one or more pre-film playlists for middle school groups.

Introduction

With funding from the National Science Foundation (NSF), *Secrets of the Universe* (SOTU) is a multimedia project that has at its core a 40-minute 3D giant screen film directed by a collaboration of K2 Communications Inc., The Stephen Low Company, and University of California Davis Department of Physics. As described on the project website:

> *Secrets of the Universe is a sweeping, 3D giant-screen adventure that immerses audiences in the greatest mysteries of our time – puzzles spanning from the infinitesimal to the infinite – and introduces the brilliant minds seeking to unravel them. Those answers await at the collision points of intellect and imagination, of theory and experiment, of the tiniest particles and most powerful forces in the universe.*

SOTU is designed for general audiences who watch the film at local science centers and specialty theaters, and also for middle school students who watch the film as part of a museum field trip. To support and extend the impact of the film for these audiences, the project features an educational website with a variety of resources, including online videos of science content and characters from the film. The summative evaluation reported here addresses the impact on 5th to 8th graders of both the online small screen videos, specifically when viewed prior to seeing SOTU, and the giant screen film.

Project goals for the middle school audience focused on increased knowledge of and interest in the science of the Large Hadron Collider (LHC)[1] and the scientists – past and present – involved in the technology and research that have contributed to our understanding of the universe. Within this middle school audience, the project further aimed to appeal to girls, with "*design approaches to the film and resources demonstrated to be effective*" (NSF proposal). To assist with project development for these audiences, two formative evaluation efforts were undertaken in 2019 by members of the evaluation team:

- To inform the final development of the film, a formative evaluation of an early fine-cut version of SOTU was conducted with 130 6th graders (Flagg et al., 2019). The evaluation assessed the appeal of the film, story, narrator, and science content; the clarity of the science content; and perceived learning from the film. The findings from this work and other formative evaluation work conducted with adults contributed to revisions that resulted in a second fine-cut version of the film.

- To assist with the focus on girls in particular, a front-end review comprising research on girls' science and physics interests and strategies for best communication practices was made available to the project team. Additionally, six female youth advisors and six STEM media gender experts reviewed the second fine-cut version of the film from the perspective of middle school girls (Knight-Williams & McCreedy, 2019). The findings in this review also had implications for the project's related online video resources tailored for middle school youth and girls.

[1] As described on the LHC website, "*The LHC is an underground particle accelerator near Geneva, Switzerland, that pushes protons or ions to near the speed of light. It consists of a 27-kilometre ring of superconducting magnets with a number of accelerating structures that boost the energy of protons or ions to form two beams travelling in opposite directions. The beams are made to collide at four points around the machine. Analyses of the particle collision data are intended to answer questions about the fundamental nature of the universe.*"

The summative evaluation of SOTU builds on the early review work and fine-cut evaluations bulleted above. The evaluation examined middle school students' experience with the SOTU giant screen film during a field trip to a local science center as influenced by previously viewing on small screens one of two types of videos: one type of pre-film video emphasized the film's LHC science content (referred to henceforth as science content videos); the second type emphasized the film's featured scientists (referred to henceforth as science character videos).

The summative evaluation included two phases. Phase 1 focused on the impact of the two types of pre-film videos and the film on 5th to 8th graders' perceived learning and interest regarding science and scientists, with an additional analysis by gender and grade. Phase 2 comprised conversation groups with middle school girls to further explore girls' experience with the science characters in the pre-film videos and film, focusing on the impact of the science characters on the girls' thoughts of scientists and their opinion of the effectiveness of the science characters as role models in encouraging their interest in science. The evaluation was implemented by Knight Williams Inc., an independent firm that specializes in the research, development, and evaluation of informal science multimedia and outreach projects.

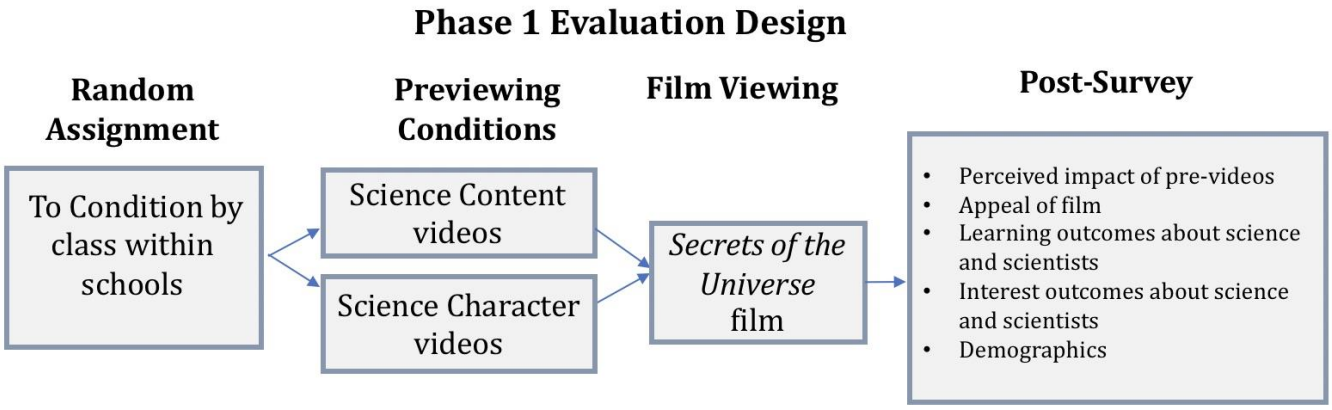
Phase 1: Impact of *Secrets of the Universe* pre-film videos and film on middle school students

Phase 1 of the summative evaluation was designed to answer the question: *Do post-film responses regarding learning and interest differ for students who see pre-film science content videos vs. those who see pre-film science character videos, and does gender or grade level play a role?*

Method

Evaluation Design[2]

Phase 1 of the summative evaluation employed a two-group posttest-only randomized design. Middle school classes were randomly assigned, within seven schools, to one of two conditions: watching either pre-film science content videos or science character videos in school. All students then watched the giant screen SOTU film at the Museum of Science and Curiosity (MOSAC) in Sacramento, CA, as part of a school field trip. An online post-viewing survey was completed at school within one to two days of the film viewing, as illustrated below. The design choice was considered preferable to a pre-post design given logistical challenges and time constraints of asking teachers to add another activity in addition to facilitating the pre-film video activity, field trip to see the film, and post-survey to gather student responses.



In addition, the Phase 1 dataset includes 20 6th to 8th grade girls from a variety of Sacramento-area schools who watched the pre-film science character videos at home and then visited MOSAC within one to two days to view the film and complete the post-viewing survey[3]. Subsequently, these girls participated in conversation groups in Phase 2 of the evaluation, described on page 41.

[2] The evaluation conformed to IRB requirements (E&I Review Services, #22107-01).

[3] In the original Phase 1 design, the girls to participate in the conversation groups were to be drawn from classes that saw science character videos in school. After classes completed the post-survey, the coordinating teachers were to distribute an information letter and a link to online consent and assent forms for girls to share and complete with their parents/guardians. Those who submitted forms were to be scheduled to participate in one of a series of session dates provided. However, because of end of year activities and conflicts, the school-based girls were not available and other girl participants were recruited independently.

Evaluation variables and questions

Table 1 presents the evaluation variables and questions relating to these variables: demographics and background; perceived effect of pre-film videos on film experience; film appeal; and the outcome variables of learning and interest based on the experience of watching both the giant screen film and one of two types of pre-film videos focused on either the science of the LHC or on the scientists featured in the film.

Table 1. SOTU evaluation variables and questions

Variables	Evaluation questions
DEMOGRAPHIC/ BACKGROUND	• How did the SOTU experience of videos and film impact girls versus boys and younger versus older grade levels for each of the questions below?
PERCEIVED EFFECT OF PRE-FILM VIDEOS ON FILM EXPERIENCE	• How did the two groups perceive the impact of their respective type of pre-film videos on their experience of the film and did the groups differ?
APPEAL OF FILM	• What did each group like and dislike about the film and did the groups differ? • How appealing did the two groups rate different aspects of the film and did the groups differ?
LEARNING OUTCOMES	• Did the two groups differ in their rating of the impact of their respective videos and film experiences on their knowledge about science and scientists? • What did the two groups learn about science and did the two groups differ? • What did the two groups learn about scientists and did the two groups differ?
INTEREST OUTCOMES	• Did the two groups differ in their rating of the impact of their respective videos and film experiences on their interest in science and scientists? • What interests did the two groups report about science and did the two groups differ? • What interests did the two groups report about scientists and did the two groups differ?

Participants

Recruitment

During the spring of 2022, staff from Knight Williams Inc. and MOSAC collaborated to share the *Secrets of the Universe* film screening and evaluation opportunity with middle school teachers in the greater Sacramento area. Using a flyer prepared by the evaluation team, MOSAC staff sent an e-blast to the museum's internal list of middle school teachers. The flyer provided information about the film, the purpose of the evaluation, and the requirement that teachers be able to commit to i) arranging for their students to watch a short set of pre-film videos at school; ii) visiting MOSAC to see the film as a class field trip within one to two days of seeing the videos; and then iii) arranging for their students to complete a 30-minute online post-viewing survey within a day or two of the field trip. To help offset the burden of coordinating these activities, teachers were provided with an honorarium for use toward a class fund. As an additional incentive, they were informed that after watching the film at MOSAC their students could spend time visiting the museum.

Though teachers were responsible for administering and coordinating the return of permission forms with their students' parents/guardians, the evaluation team provided them with following information to include in their forms: a brief synopsis of the film, a description of the three phases of activities their students would be doing (outlined above), and information about students'

participation being voluntary, that they could withdraw at any time, and that their responses were confidential with results reported in the aggregate.

The additional 20 girls, who were recruited independently to participate in conversation groups, also learned about the evaluation opportunity through comparable letters distributed by local teachers and evaluators to their parents or guardians, with the evaluation team coordinating the return of permission forms. The girls received honoraria and were given the additional incentive that they could spend time at MOSAC visiting the museum after their SOTU evaluation participation.

The final student sample analyzed in Phase 1 (N = 190) includes students who completed all parts of the study design: those who watched and recalled one of the two sets of pre-film small screen videos; traveled to MOSAC to view the giant screen SOTU film and visit the museum exhibits; and completed all post-survey questions within one or two days of their museum field trip.

Demographic and background information

Table 2 presents demographic and background information for the 190 middle school students who completed the full procedure. Of these students, 96 viewed the pre-film science content videos and 94 viewed the pre-film science character videos. The two independent pre-film viewing groups did not differ significantly with respect to gender, age, and minority/non-minority distributions. The groups differed in their grade distribution, with significantly more 5th graders in the content group and significantly more 7th graders in the character group (χ^2 (3, N = 190) = 22.80, $p < .0001$).

Table 2. Students' demographic and background information (N = 190)

Demographic/ background factor	Categories	Pre-film science content viewers (n = 96)	Pre-film science character viewers (n = 94)
Gender	Female	52%	59%
	Male	45%	34%
	Non-binary	3%	3%
	No response	0%	4%
Age group	Age range	10-14	11-14
	Mean	12.7	13
Grade	5th	15%	0%
	6th	24%	19%
	7th	3%	16%
	8th	58%	65%
Racial/ethnic group	African American/Black	4%	4%
	Asian	8%	16%
	Hispanic or Latino	48%	21%
	Multiracial	18%	32%
	Native Hawaiian or Pacific Islander	0%	1%
	White	19%	23%
	No response	3%	2%

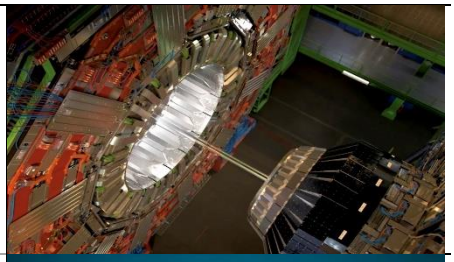
Materials

Pre-film videos

While all students viewed the same SOTU film at MOSAC, they watched with their class or at home one of two types of pre-film videos: science content videos focused on the science of the LHC or science character videos focused on past and present scientists featured in the film. The videos are described and linked in Table 3 below. The videos were all drawn from the SOTU website, and each set of videos (content or character) was edited into a 7-minute experience for viewing on individual computers or on a large TV on a stand at the front of the classroom.

Table 3. Pre-film video descriptions, images, and links

Science content videos

Great Machines in Science: The Large Hadron Collider (1 minute)	A male narrator explains over visuals the LHC science goal of colliding tiny particles.	
Inside the world's largest particle accelerator (6:14 minutes)	A male narrator and scientist explain and illustrate how the LHC works.	
Science character videos		
Secrets of the Universe online trailer (1:44 minutes)	The film's central scientist, Dr. Manuel Calderón de la Barca Sánchez, narrates over visuals of the inside of the LHC and shows many current scientists working together, describing how their work builds on the shoulders of past scientists.	
Team Spotlight: Manuel Calderón de la Barca Sánchez (2:11 minutes)	Dr. Manuel Calderón de la Barca Sánchez, narrator of the giant screen film, talks about the diversity of LHC scientists, the goal of LHC science, and the value of LHC research to medicine.	
Character Profile: Santona Tuli (3:05 minutes)	Dr. Santona Tuli appears in the film and in this pre-film video talks about submitting her doctorate thesis, the film's science research, and where LHC scientists come from and what they do. She also explains her back-ground and speculates on her future.	

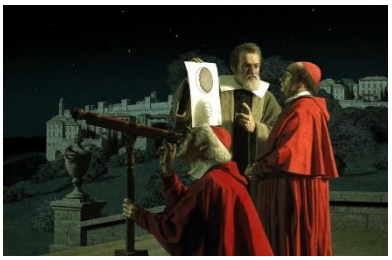
***Secrets of the Universe* giant screen film**

Students viewed the 40-minute SOTU film in MOSAC's 46' full-dome theater. Viewers travel with Dr. Manuel Calderón de la Barca Sánchez as he journeys to the LHC, the largest scientific instrument ever built. Viewers also learn of past and present scientists who have tried to understand the fundamental nature of the universe.

The film looks inward at the universe from the use of microscopes to the collisions of ions in the LHC (illustrated at top of Table 4) and outward from the first use of telescopes to an entirely different form of observation: LIGO, a detector of gravitational waves (illustrated at bottom of Table 4).

Table 4. Images from *Secrets of the Universe*






Procedure

Prior to watching the pre-film videos, the classroom teachers provided a short unbiased verbal introduction to the respective set of videos that their class viewed, as follows:

- Science content videos*: Before we go to see the film Secrets of the Universe at MOSAC, we are going to watch some short videos today about the science of the Large Hadron Collider in Geneva, Switzerland;* or

- Science character videos*: Before we go to see the film Secrets of the Universe at MOSAC, we are going to watch some short videos today about the scientists who work with the Large Hadron Collider in Geneva, Switzerland.*

Students then watched the 7-minute video their class was assigned to view, either on their laptop (typically a Chromebook) or on a large widescreen TV on a stand at the front of the classroom. One to two days later, they viewed the film at MOSAC as part of a school field trip, with two evaluators present to observe each screening. Finally, within one to three days after the field trip, teachers introduced students to an online post-film survey at school using a script provided by the evaluation team. The script informed students that they were invited, along with several other middle school classes in the Sacramento area, to provide feedback about their experience with the pre-film videos and film through an online survey. They were also asked to please keep the following points in mind: 1) Participation was voluntary and they could quit at any time; 2) Their responses were private and would be combined with those from other students; 3) As they were are being asked for their opinions, there were no right or wrong answers, and to please provide their honest feedback as best they can, without the help of others; 4) The survey may take up to 30 minutes to complete, and to please take their time with the questions; 5) Their feedback would help inform how museums use the videos and film, and also how producers design future media to

support student learning about science; and 6) The findings from the evaluation would be summarized in a report for the National Science Foundation which provided funding for the SOTU project.

Additionally, students were directed to notice that the first set of questions would ask them about the pre-film videos they watched, so to please keep in mind which set they watched, and to ask their teacher for help if needed. After that, they would be asked a few questions about the film they watched at MOSAC, followed by a final set of questions about their overall experience watching both the videos and film.

The additional 20 girls. who were recruited to participate in conversation groups, read at home in an online sign-in page the information that the in-school students had received from their teachers. They then clicked to watch the pre-film character videos on a computer screen. Like the field trip students, the girls watched the film at MOSAC within one to two days. They subsequently completed the post-viewing survey at MOSAC, with the evaluator providing the same information about the survey that the teachers provided to their students.

The survey included both closed and open-ended questions to address the evaluation questions listed in Table 1. The full survey is shared in Appendix 1.

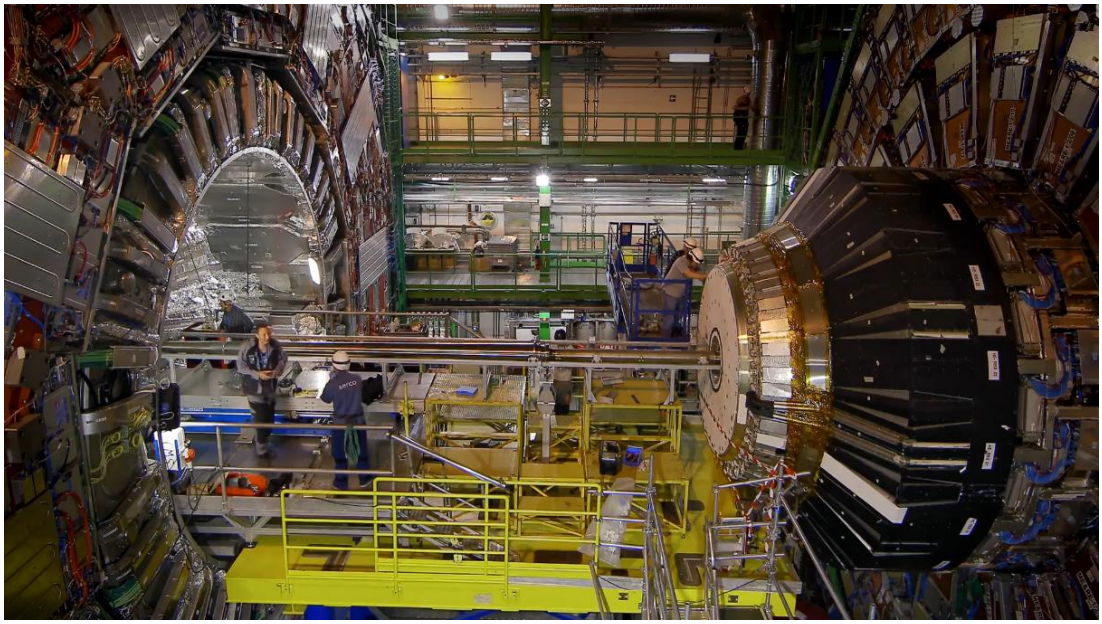
Analysis

Content analyses were performed on the qualitative data generated in the open-ended questions. The analysis was both deductive, drawing on the project's goals and objectives, and inductive, looking for overall themes, keywords, and key phrases. Responses to six open-ended questions where students were asked to "describe two things..." were coded as one response; thus, category percentages may add up to more than 100%. Illustrative quotes are in some cases lightly edited to correct spelling and improve readability.

Basic descriptive statistics were performed on the quantitative data generated from the evaluation. To address the evaluation questions in Table 1 about video group, gender, and grade level differences, the statistics of two-sample two-tailed *t*-tests were applied to quantitative data and Fisher exact tests applied to qualitative data. Gender included only those students who specified female (n = 105) or male (n = 75) identification. In addition, due to the grade by video group imbalance, our analyses combined grades 5, 6, and 7 (n = 73) to form a younger grade level and looked for differences with the older 8th grade level (n = 117). A statistical test that gave a *p*-value, or probability value, lower than .05 is reported as "statistically significant."

Results

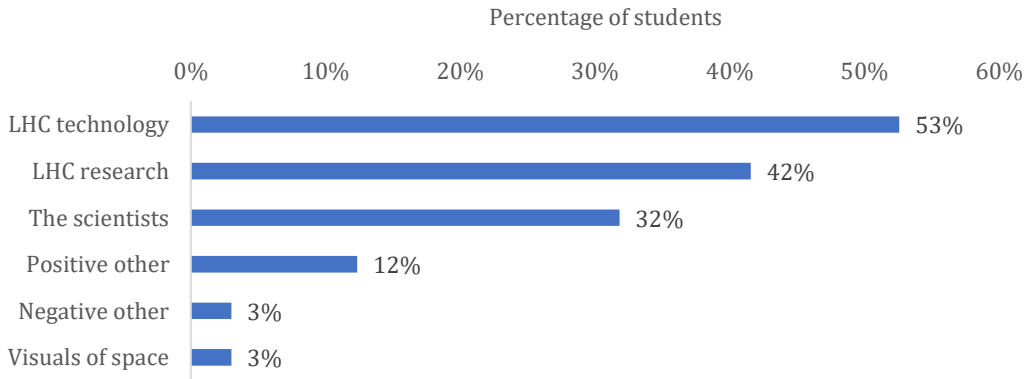
Part 1. Perceived effect of pre-film videos on film experience



1.1 What about the pre-film videos stood out for students

Students were asked to recall the videos they saw before their field trip and to explain what about the videos stood out for them. As shown in Figure 1, of those who provided answers about what stood out for them in the videos[4], half (53%) commented on LHC technology, such as the Collider, its size and location, and how it works. Two-fifths (42%) pointed to aspects of LHC research on atoms, protons, and collisions. One-third (32%) commented on the scientists in the videos. One-tenth (12%) shared other responses that were positive in nature, while less than one-tenth each shared other responses that were negative (3%) or said the visuals of space stood out to them (3%). Examples of students' comments about what stood out are in Table 5 on the next page.

Figure 1. What about the videos stood out for students (n = 154)



[4] Not included in section 1.1 are 18 students from the first school to complete the survey, who were not asked this question. Also not included are 14 students who gave a response that was not specific to the videos and four who said they did not know or couldn't remember.

Those who reported that what stood out for them in the videos was LHC technology or LHC research were significantly more likely to have watched the content videos (72%, 57%, respectively) than the character videos (29%, 23% respectively; Fisher exact tests, $p < .0001$).

Those who reported that what stood out for them were the scientists were significantly more likely to have watched the character videos (54%) than the content videos (14%; Fisher exact test, $p < .0001$). Additionally, those who were coded as giving positive other responses were significantly more likely to have watched character videos (23%) than content videos (4%; Fisher exact test, $p = .0003$).

Table 5. What about the videos stood out for students (n = 154)

LHC technology (53%)

- *Something in the video that stood out to me was that they used magnets to control the direction of the collision of the protons.*
- *The thing that stood out for me was the circle under the Earth.*
- *A thing that stood out to me was how far the [Large] Hadron Collider stretched out. Also, why in Switzerland?*
- *There was a lot of engineering involved.*

LHC research (42%)

- *I thought it was interesting that particles were being slammed into each other to split them.*
- *All I can remember is…how small photons move at near light speed with over 100 million collisions per second.*
- *Atoms, and the strongest force in the universe that is the starting point of everything.*
- *The part that stood out to me is when I learned how they collide protons to see what they are made of and to see if anything new happens.*

The scientists (32%)

- *It really showcases what scientists were trying to do with the next steps in science.*
- *I saw how different scientists from all around the world came to Switzerland to combine their thoughts about the atoms and how the universe started.*
- *I can remember they were talking about this one scientist and the work he did and then another younger scientist talked about the work she did I think.*
- *The part of the videos that stood out to me was when they were talking about it doesn't matter where you come from or who you are.*

Positive other (12%)

- *They educated me about what science truly is.*
- *The graphics stood out to me.*
- *They were very well made. Showed what the project was about.*

Negative other (3%)

- *I noticed the repeated use of similar or identical clips, which made me think less of the total film.*
- *It was boring and not interesting and wasn't very entertaining.*

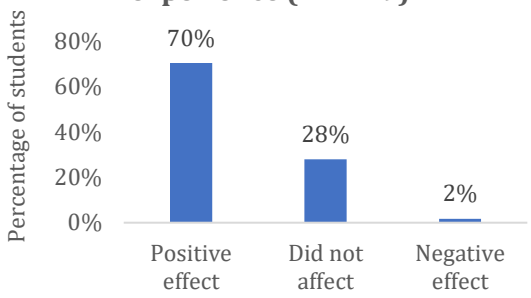
Visuals of space (3%)

- *I don't really remember much about the videos, but I do know that the trailer about the universe was pretty cool, seeing…stars.*
- *The graphics in space.*

1.2 How watching the pre-film videos affected students' experience of the film

Figure 2 presents how students thought watching their respective videos at school or at home affected their experience of the film at MOSAC.[5] More than two-thirds (70%) thought the videos had a positive effect on their film experience, more than a quarter (28%) said they didn't affect their film experience, and very few (2%) said the videos negatively affected their film experience.

Figure 2. How students thought the videos affected their film experience (n = 149)



For each choice in Figure 2, students were asked to explain, as best they could and as specifically as they could, how the videos affected their experience of the film at MOSAC. Of the sample of 149 students, the main positive effects reported were that the videos increased their understanding of the film's topics (including the LHC, how it works, and the research being done there) (30%) and were a good preview for the film (27%). The main reason given for no effect was that students did not like or were ambivalent about the videos (9%).

Those who watched content videos were significantly more likely to say the videos increased their understanding of the film's topics (42%) compared with those who watched character videos (16%; Fisher exact test, $p = .001$).

Examples of the ways students thought the videos had a positive effect, no effect, or a negative effect on their film experience are detailed in Table 6, below and on the next page.

Table 6. How watching the videos affected students' film experience (n = 149)

Positive effect (70%)

Increased understanding of the film's topics (30%)

- *The videos gave me some background information about what the Collider was, and the basics of how it works. When I watched the movie I could connect the information to the videos and understand what they were talking about.*
- *I feel as though if we didn't watches the video I would be greatly confused with the movie since they started on the subject right where we left off.*
- *Well, it helped me understand [the film] better because some things got kind of hard to understand, but then I remembered things from the [videos] which helped me understand better.*
- *It positively affected my experience by telling me about the LHC and why it was crucial to this film. It also affected my experience by explaining some things about atoms….*

Good preview for the film (27%)

- *It made me look forward to the movie more and gave me some background info on what it was about.*
- *They gave me a preview on what I would be seeing and learning.*
- *The videos positively affected my experience by getting me excited by seeing what the [film] is about and seeing what it would be like with the realisticness of it.*
- *It positively affected my experience because the video got me exited to see the real movie and so when I…saw the movie I felt as if it made my experience better.*

[5] Not included in section 1.2 are 18 students from the first school to complete the survey, who were not asked this question, as well as 22 students who gave a response that was not specific to the videos' effect on their film experience and one who said they did not know.

Table 6 continued. How watching the videos affected students' film experience (n = 149)

Increased interest in film's topics (15%)

- *The videos and the film positively affected my experience because I have learned so much and it made me think about new scientific opportunities and grew my passion for science.*
- *The videos positively affected my experience by giving me interest in how the Large Hadron Collider works and giving us more interest in the Universe.*
- *It positively affected my experience because the videos made me be more interested and it made me more curious.*

Liked seeing or learning different things from videos and film (11%)

- *Because the video we saw in school didn't show me everything [the film] showed me, so it was pretty cool seeing new things and seeing how they built the machines.*
- *There were…different stories in the video. I feel like when the video was talking about atoms I found it really interesting and also remembering that I learned the things that were in the video in my science class.*
- *How the videos positively affected my experience watching the film was it gave me background information on some of the main scientists.*

Other (1%)

- *It affected me by showing me the experience they had traveling for [a] good cause.*

No effect (28%)

Ambivalent about or didn't like videos (9%)

- *I didn't feel any emotion towards the videos nor did I have any interest.*
- *Because as cool as it was it just gave me some background on the videos, which was nice, but it didn't make the movie better or worse.*
- *Because it did not make me more or less excited for [the film], I stayed at the same level of excitement.*

Forgot about or didn't pay attention to videos (7%)

- *I did not remember much about the videos, and when I was watching the film I did not think about [them] at all*
- *Because I didn't know I was supposed to be paying actual attention to [the videos]*

Videos and film were on the same subject (5%)

- *It was all just the same for me they were both about the same thing.*
- *This is because it was just talking about the same topics that the movie was talking about, so what is even the point of watching the intro videos?*

Videos and film were too dissimilar (3%)

- *[The videos] didn't have much to do with [the film].*
- *Well because the trailer videos were a lot about the [Large] Hadron Collider and its parts but it didn't tell us how it worked. Same for the team spotlight video, there wasn't any real point to seeing that because we weren't really introduced to the people working there that well.*

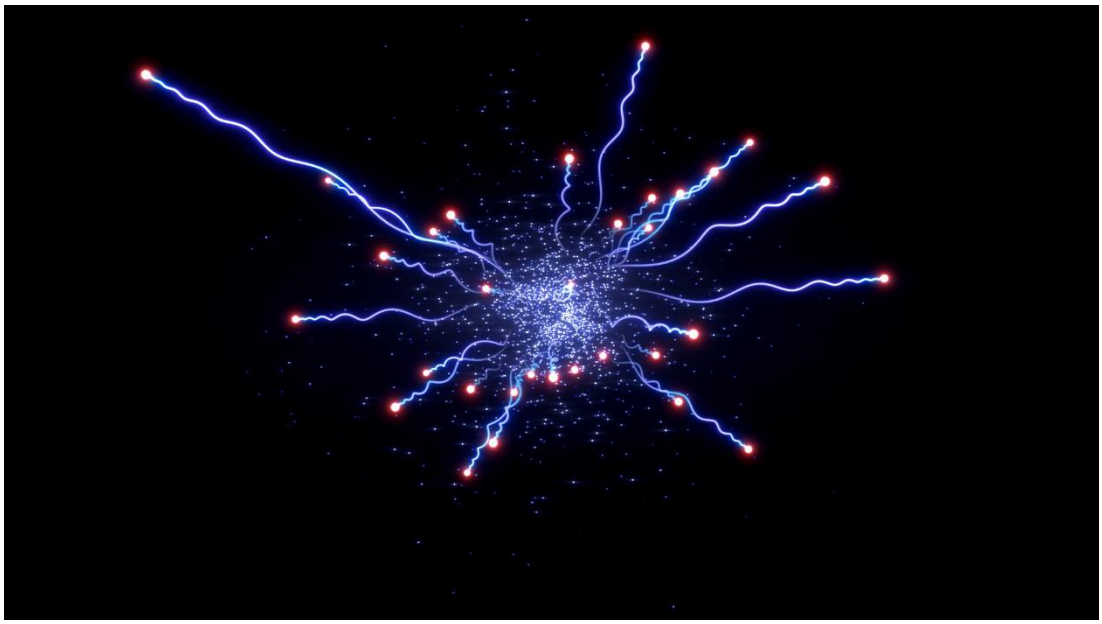
Other (3%)

- *There is no specific reason, I had already known about the Large Hadron Collider before the videos, so I was being told things I was already familiar with.*

Negative effect (2%)

- *The video about the Large Hadron Collider told us an explanation about what it does, so when we watched the movie, it was telling me stuff I already knew.*
- *It was so boring and I wanted to see the Collider thing but apparently it's not even in [at MOSAC] so what was the point of going?*

Part 2. Appeal of *Secrets of the Universe* film



2.1 How much students liked the film overall

When asked to rate how much they liked or disliked the film overall on a scale from 1 (disliked) to 5 (liked), students somewhat liked it on average (*Mdn* = 4.0, *M* = 4.0). Table 7 shows the percentages of students who gave each rating.

Table 7. Frequency distribution of how much students liked the film overall (N = 190)

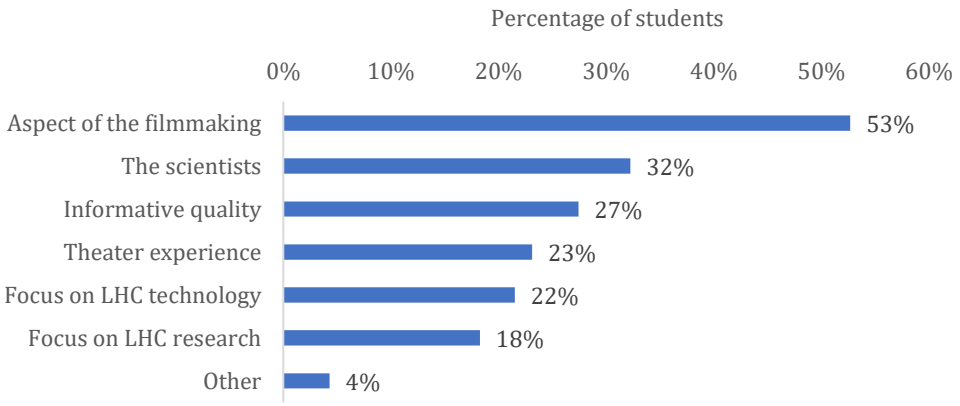
	1	2	3	4	5	
Disliked	1%	7%	17%	45%	31%	Liked

The younger grade level liked the film overall significantly more than the older 8th grade level (*M* = 4.3 vs 3.8; $t(173) = 3.91$, $p = .0001$).

2.2 What students liked most about the film

Figure 3 shows what students liked most about the film. Of those who provided answers about what they liked most[6], more than half (53%) of the students pointed to an aspect of the filmmaking; within this category, nine-tenths (90%) commented specifically on the film's visuals and one-quarter (26%) remarked on other aspects of the filmmaking, including the editing, music, film length, and pacing.

Figure 3. What students liked most about the film (n = 186)



Among other aspects students liked most about the film, one-third (32%) pointed to the scientists, and about a quarter each cited the informative quality of the film (27%) and the theater experience (23%). About a fifth each described liking the film's focus on LHC technology (22%) and LHC research (18%), and less than one-tenth (4%) shared other responses. Examples of students' comments about what they liked most are in Table 8 on the next page.

Those who watched the content videos were significantly more likely to report that what they liked about the film was LHC technology (28%) and LHC research (27%) compared with those who watched the character videos (15%, 10% respectively; Fisher exact tests, $p = .049$ for both coded categories). Girls were significantly less likely than boys to report liking the focus on LHC technology (9% vs 40%; Fisher exact test, $p = .0001$) and the focus on LHC research (13% vs 26%; Fisher exact test, $p = .03$).

Girls were significantly more likely than boys to report liking an aspect of filmmaking (60% vs 40%; Fisher exact test, $p = .009$), and girls were significantly more likely than boys to report liking visuals as a sub-category of an aspect of filmmaking (58% vs 30%; Fisher exact test, $p = .0002$).

Students in the younger 5th, 6th, and 7th grade level were significant more likely than 8th graders to report liking the scientists (43% vs 25%; Fisher exact test, $p = .016$).

[6] Not included in section 2.2 are two students who said there was nothing they liked, one who gave a response that wasn't specific to the film, and one who said they did not know.

Table 8. What students liked most about the film (n = 186)

Aspect of the filmmaking (53%)

- *It was filmed well*
- *I liked the visuals and CGI in the film because they were interesting to see.*
- *I liked the part where they showed the atoms hitting each other because the model that they did and how they explained what was happening was amazing. I also liked the part where they showed the universes because what they did with it was very detailed.*
- *One thing that I liked was the animation of seeing the Collider work*
- *I loved…the editing of the film*
- *I thought that the music enhanced the experience and made it more dramatic and made it more engaging than just a normal documentary type movie.*
- *Another thing that I liked was that the film wasn't too long or too short.*
- *I found that the film had a good pace*

The scientists (32%)

- *Facts about the famous people who made scientific history.*
- *The second thing I liked about the film was all the people who were involved in the research, from the Greek philosophers to the people who are still working on it today.*
- *I like how lots of countries are pairing up with each other to find out new things in science.*
- *[I liked] that it showed how much energy and time it took for people like this to conduct experiments and that I should be more thankful for them and what they do.*

Informative quality (27%)

- *I liked how the film was at our grade level; meaning not too high and not too low so that I can understand what they are saying and still be interested in it*
- *I liked that there was a narrator to explain everything, that helped me understand what the film showed me.*
- *I like how the movie gave visual examples and verbal examples which helped clear things up.*
- *[One thing] that I enjoyed in the film was the way it was made it was very interesting and I learned new information.*

Theater experience (23%)

- *It was cool to look at a dome like that*
- *The big screen because it is most likely a first-time experience for a lot of people.*
- *I liked the technology that made you think that you're observing it in person.*

Focus on LHC technology (22%)

- *It was awesome to see how the machine worked to make the atoms collide and how that would affect things.*
- *I also liked how they explained the Collider, it was not too difficult to understand and yet explained everything with great detail.*
- *The reasoning behind the creation of the Large Hadron Collider.*
- *I love that they showed us how they built the time machine. I always believed that we would be able to go back in time and they showed us that we can actually go back in time even if it was a couple of seconds.*

Focus on LHC research (18%)

- *The first thing I liked most about the film was the explanation of the collisions.*
- *It talked about science and it was about atoms and what we have learned…*
- *The explanation of photons*
- *[One thing] I liked about the film was the people talking about cool things they learned about*

Other (4%)

- *I liked everything about it.*
- *I also liked the topic.*

2.3 What students did not like about the film

Figure 4 shows what students did not like about the film. Of those who provided answers about what they did not like[7], two-fifths (43%) pointed to the theater experience, for example finding the seating uncomfortable, possibly because they were seated toward the front of the dome theater and had to lean their heads back to view aspects of the film. Image 1 shows the front rows of an adult audience viewing SOTU in the MOSAC theater. A quarter (24%) said the film was confusing or not well explained, and about a fifth each found the film too long (21%) and boring (19%). More than a tenth each thought it contained disjointed or unnecessary information (14%) or commented on an aspect of the filmmaking (12%). Less than a tenth each disliked a specific film topic (9%), found the information repetitive (7%), said they wanted more information (5%), or shared another response (6%). Examples of students' comments about what they did not like are in Table 9 on the next page.

Figure 4. What students did not like about the film (n = 140)

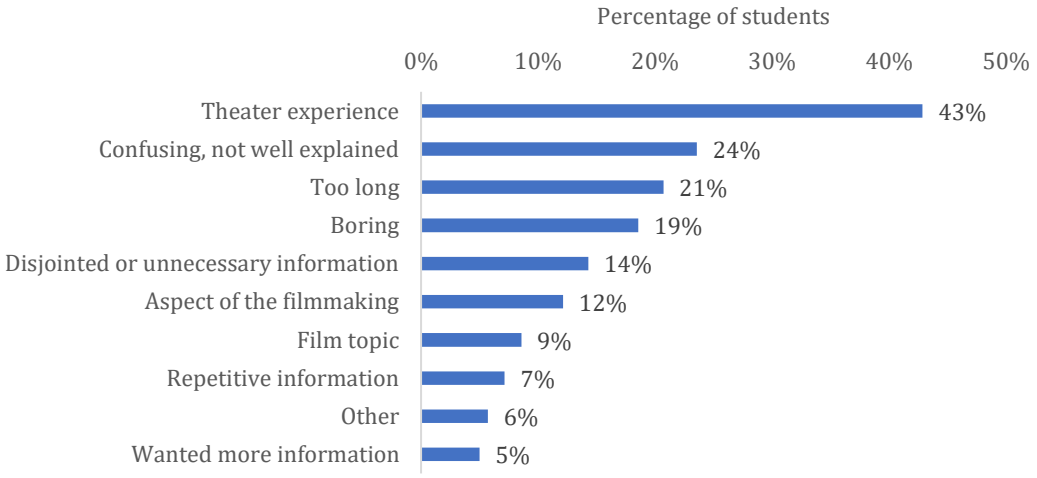


Image 1. An adult audience watching *Secrets of the Universe* at MOSAC, from the UC Davis website

[7] Not included in section 2.3 are 48 students who said they had no dislikes and two who said they didn't know or couldn't remember.

Table 9. What students did not like about the film (n = 140)

Theater experience (43%)

- *I did not like the fact that the seats were tilted backwards because it hurt my neck…*
- *One thing that I did not like was the chairs. I did not like the chairs because if you sit on them for long your neck starts to hurt.*
- *The only thing I didn't like was how we watched the movie, sticking our head straight up, hurt.*
- *There was a lot of movement in the film which made me dizzy since the screen was around the ceiling.*
- *Some things were [sort of] warped because it was projected at the top, if that makes any sense*

Confusing, not well explained (24%)

- *I felt like it was hard to follow along with the film because there was so much going on.*
- *I didn't like how there was a lot of information given all at once. The information made sense there was just too much of it that you can't keep up with what you're being told.*
- *I did not like…when the narrator didn't explain something. I disliked this because I could be left wondering about something without an explanation.*
- *The people from UC Davis said they had a job with the camaras but they didn't really explain why, and I didn't really understand the purpose of the UC Davis scientists.*
- *It never really explained what the "time machine" proved. And it never really gave us any results.*
- *It was also confusing because they said they were "time traveling."*

Too long (21%)

- *Two things I didn't like about the film was that it was too long, making the viewer lose interest. Another thing I didn't like about the film was that when you thought it was over it keeps on going.*
- *One thing I did not like about the film was that it was very long. As interesting as it was, there were some parts like the explanation of why the people went to the pub that were kind of long.*

Boring (19%)

- *It also seemed to bore me at times whenever the person was speaking.*
- *Wasn't interesting and it was boring*

Disjointed or unnecessary information (14%)

- *Something I disliked about the film was the constant change of topic. I didn't like that because it would make me confused on what we were watching and it would be hard to process every detail.*
- *One thing I did not like about the film was that they jumped from one idea to another and then went back to the first idea. It was hard to keep track of what they were talking about.*
- *I also disliked when they gave information that is not relevant. I disliked this because it is unnecessary.*
- *Something I did not like about the film was the fact that the guy who was narrating was talking about snowboarding when the whole point of the movie was [the] Collider*

Aspect of the filmmaking (12%)

- *I didn't like the soundtrack. It was loud and bubbly when the moments were tense, and intense when the cat was staring out the window.*
- *The way the film was put together. The whole film looked like something you would make on we-video.*
- *There was no switch in pace, only at the start and the end. The middle felt filled in so it made it harder to follow.*

Film topic (9%)

- *I did not like the part where the cat died. It was sad.*
- *I also didn't like how they talked about Charles Darwin, because he was wrong about evolution.*
- *I only have one thing that I did not like…seeing the bugs and insects on our bodies because it was really disgusting to me…*

Repetitive information (7%)

- *Some parts were a little repeated at the end. It felt like you were stretching the movie on longer without even needing to.*
- *I didn't like how it kept saying the same things over again. I also dislike how they kept repeating some information and evidence.*

Other (6%)

- *I didn't like how it will probably not ever affect me*
- *I also didn't like how there were houses and people living inside the [LHC] circle*

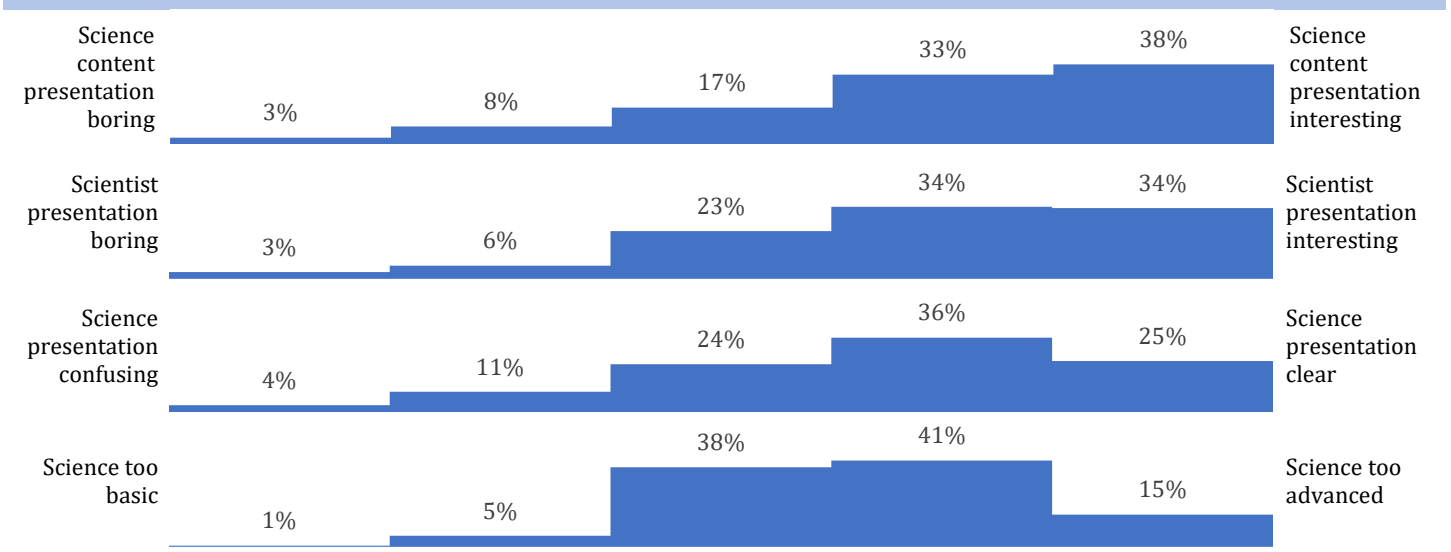
Wanted more information (5%)

- *I did not like that they didn't talk more about the Large Hadron Collider, and how it works, because I want to know more about it.*
- *I would have liked to learn a bit more about who thought of the Large Hadron Collider and how it was constructed. Like how they built it underground. Everything else I thought was pretty good.*

2.4 Students' ratings of the film's presentation of science and scientists

On a scale of 1 to 5, students rated how they felt about the film's presentation of science content and scientists as well as the clarity of the film's science presentation and the level of science in the film. On average, students found both the presentation of science content and scientists somewhat interesting (*Mdn* = 4.0, *M* = 3.9 each), thought the film was somewhat clear (*Mdn* = 4.0, *M* = 3.7), and found the level of science somewhat too advanced (*Mdn* = 4.0, *M* = 3.7). Table 10 shows the percentages of students who gave each rating.

Table 10. Frequency distribution of students' ratings of the film's science presentation (N = 190)



The younger grade level rated the presentation of science content as significantly more interesting compared with the older 8th grade level (*M* = 4.2 vs 3.8; *t*(165) = 2.31, *p* = .022) and also rated the presentation of scientists as significantly more interesting compared with the older 8th grade level (*M* = 4.1 vs 3.8; *t*(172) = 2.11, *p* = .037). The younger grade level also found the level of science significantly more advanced for them compared with the older 8th grade level (*M* =3.8 vs 3.5; *t*(184) = 2.65, *p* = .009).

Part 3. Impact of videos and film on learning outcomes

3.1 How students thought the videos and film affected knowledge of science

Students indicated how their experience with the videos and film affected their knowledge of science, selecting did not affect, increased a little, increased somewhat, increased moderately, or increased a lot. To calculate Median and Mean, numbers ranging from 0 to 4 were assigned to these options. On average, students thought their knowledge of science somewhat increased (*Mdn* = 2.0, *M* = 2.3). Table 11 shows the percentages of students who gave each rating.

Table 11. Frequency distribution of students' ratings of how the videos and film affected their knowledge of science (N = 190)

Did not affect 0	Increased a little 1	Increased somewhat 2	Increased moderately 3	Increased a lot 4
7%	16%	28%	33%	15%

The younger grade level felt their knowledge increased significantly more compared with the older 8th grade level (*M* = 2.6 vs 2.1; *t*(155) = 3.17, *p* = .002).

Students' ratings of statements of how SOTU media affected knowledge of the Collider

On a scale of 1 (strongly disagree) to 5 (strongly agree), students rated four statements about how their experience with the videos and film affected their specific knowledge of the Collider. On average, students agreed that they learned more about how difficult it is to make the Collider work perfectly (*Mdn* = 4.0, *M* = 3.9), how the Collider works to produce particle collisions (*Mdn* = 4.0, *M* = 3.8), and how the Collider can be used to explore fundamental questions in science (*Mdn* = 4.0, *M* = 3.6). They were neutral as to whether they had learned more about how the Collider was engineered and constructed (*Mdn* = 3.0, *M* = 3.4). Table 12 shows the percentages of students who gave each rating.

Table 12. Frequency distribution of students' ratings of statements about how the videos and film affected their knowledge about the Collider (N = 190)

As a result of my experience with *Secrets of the Universe*, I learned more about…	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
how difficult it is to make the Collider work perfectly.	1%	8%	22%	32%	37%
How the Collider works to produce particle collisions.	3%	6%	28%	38%	26%
How the Collider can be used to explore fundamental questions in science.	2%	8%	35%	33%	22%
How the Collider was engineered and constructed.	3%	14%	36%	31%	16%

Those who saw the content videos agreed more strongly with the statement "I learned more about how the Collider works to produce particle collisions" compared with those who saw the character videos (*M* = 4.0 vs 3.6; $t(185) = 3.29$, $p = .001$).

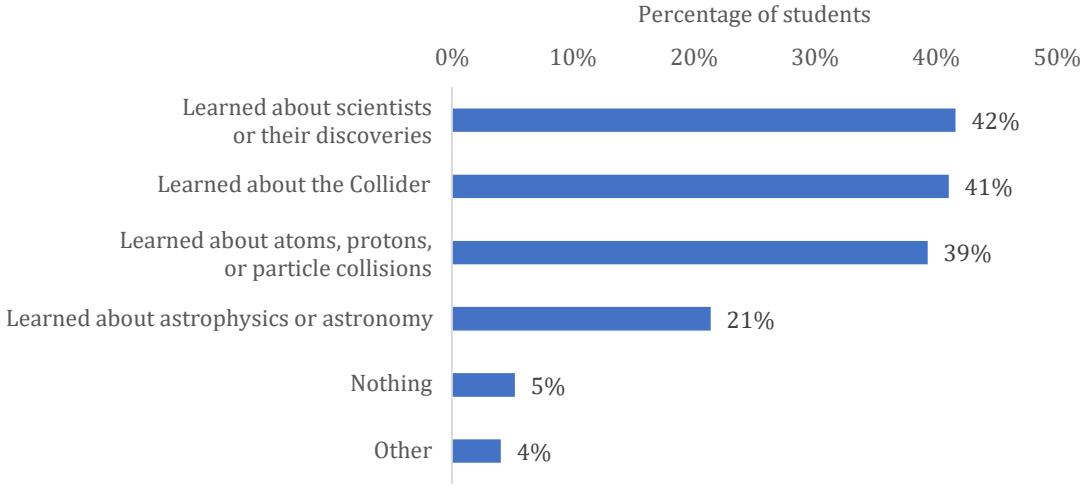
Girls disagreed more strongly with the statement "I learned how the Collider works to produce particle collisions" compared with boys (*M* = 3.6 vs 4.0; $t(163) = 2.46$, $p = .01$).

3.2 What students thought they learned about science

Students were asked what they learned about science that they did not know before their experience with the SOTU videos and film. As shown in Figure 5, of those who provided answers about what they learned about science[8], two-fifths each thought they had learned about scientists or their discoveries (42%), the Collider (41%), and atoms, protons, or particle collisions (39%). One-fifth (21%) thought they learned about astrophysics or astronomy. Less than one-tenth each said they learned nothing (5%) or shared another response (4%).

Among those students who identified something they thought they learned about science from the videos and film, the evaluation team noted three areas of confusion in some of their responses: confusion about the Collider's "time machine" capabilities, confusion about the heat generated by the collisions, and confusion about the force holding together quarks. Examples of students' comments about what they thought learned about science are in Table 13 on the next page, including those in areas where students did not seem to fully understand the videos and/or film.

Figure 5. Things students learned about science from the videos and/or film (n = 173)



Those who watched content videos were significantly more likely to report that they learned about the Collider compared with those who watched character videos (51% vs 31%; Fisher exact test, p = .009).

Girls were significantly less likely than boys to report learning about the Collider (31% vs 51%; Fisher exact test, p = .02), and girls were significantly more likely than boys to report learning about scientists or their discoveries (51% vs 31%; Fisher exact test, p = .01).

[8] Not included in section 3.2 are six students who said they did not know or could not remember and 11 who gave answers that were not specific to the content of the videos and/or film.

Table 13. Things students thought they learned about science from the videos and/or film (n = 173)

Learned about scientists or their discoveries (42%)

- *I also learned about famous scientists.*
- *I also learned how scientific methods of exploration and discovery have changed over the years.*
- *I also did not know how much people were trying to answer the world's biggest question.*
- *I did not know the person that made the periodic table.*
- *I did not realize how powerful radiation was. I did not know about the background to telescopes and microscopes.*

Learned about the Collider (41%)

- *I learned that the Large Hadron Collider causes billions of collisions in a mere second. I also learned that it moves at near light speed.*
- *How the Collider can be used to explore the universe.*
- *Particles can travel at the speed of light and strong magnets cause the particles to go fast*
- *Another thing is how scientists are now trying to invent a time machine.*
- *That we have a possibility to time travel.*
- *I did not know that they are trying to make a time travel machine.*

Learned about atoms, protons, or particle collisions (39%)

- *I did not know about what came before atoms…that it's much hotter than the sun, like 100 thousand times hotter.*
- *That when 2 atoms collided it created a heat wave hotter than the sun and that all periodic elements are made of the same three things; protons, neutrons, and atoms.*
- *I did not know that you can combine/collide 2 lead atoms and not have an explosion.*
- *I didn't know there is a type of atom hotter than the sun. I also didn't know the hadron even existed.*
- *I learned that there is something 1 million times hotter than the sun.*

Learned about astrophysics or astronomy (21%)

- *I learned that atoms started when the Big Bang happened billions of years ago.*
- *I learned what happened right as the big bang started. I also learned that in the beginning of the big bang the space was too hot for particles to do anything.*
- *I also learn that atoms can be a hint to find the "who & why" of the universe*
- *I learned that when stars crash into each other, they release gravity waves.*
- *There is this great force in the universe that no one named*
- *There [are] really powerful forces and it all started with one star*

Other (5%)

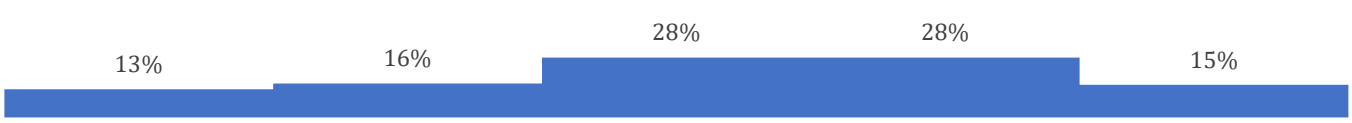
- *I also learned how physics isn't just math. I thought it was cool how they actually get real results and answers.*
- *It can help you in many ways, and you will need it depending what job you got.*

3.3 How students thought the videos and film affected knowledge of scientists

On average, students thought their experience with the videos and film somewhat increased their knowledge of scientists (*Mdn* = 2.0, *M* = 2.2). Table 14 shows the percentages of students who gave each rating.

Table 14. Frequency distribution of students' ratings of how the videos and film affected their knowledge of scientists (N = 190)

Did not affect 0	Increased a little 1	Increased somewhat 2	Increased moderately 3	Increased a lot 4
13%	16%	28%	28%	15%



The younger grade level felt their knowledge of scientists increased significantly more compared with the older 8th grade level (*M* = 2.5 vs 2.0; *t*(164) = 3.01, *p* = .003).

Students' ratings of statements of how SOTU media affected knowledge of scientists

On a scale of 1 to 5, students rated five statements about how their experience with the videos and film affected more specific knowledge of scientists, as presented in the media they watched. On average, students agreed that they learned that scientists from the past can play an important role in the science that is practiced today (*Mdn* = 4.0, *M* = 4.1) and that scientists from many countries work together in teams (*Mdn* = 4.0, *M* = 4.0). They also agreed that they were more aware that young people from every background can become scientists (*Mdn* = 4.0, *M* = 3.9), that they better understood the struggles scientists go through with their research (*Mdn* = 4.0, *M* = 3.9), and that they were more aware of the passion and excitement that scientists have for their work (*Mdn* = 4.0, *M* = 3.9). Table 15 shows the percentages of students who gave each rating.

Table 15. Frequency distribution of students' ratings of statements about how the videos and film affected their knowledge of scientists (N = 190)

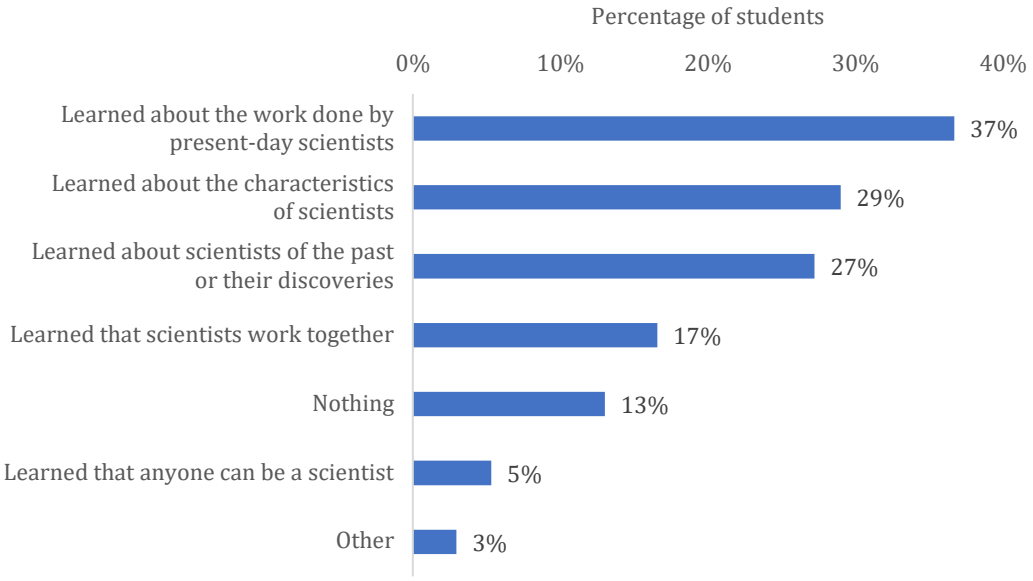
As a result of my experience with *Secrets of the Universe*...	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
I learned that scientists from the past can play an important role in the science that is practiced today.	2%	4%	18%	36%	40%
I learned that scientists from many countries work together in teams.	2%	4%	24%	35%	35%
I am more aware that young people from every background can become scientists.	3%	4%	23%	37%	33%
I better understand the struggles scientists go through with their research.	1%	5%	26%	39%	29%
I am more aware of the passion and excitement that scientists have for their work.	1%	4%	29%	38%	28%

Those who saw the character videos agreed more strongly with the statement "I am more aware that young people from every background can become scientists" compared with those who saw content videos (*M* = 4.2 vs 3.7; $t(182) = 4.24$, $p = .001$).

3.4 What students thought they learned about scientists

Students were asked what they learned about scientists that they did not know before their experience with the SOTU videos and film. As shown in Figure 6, of those who provided answers about what they learned about scientists[9], two-fifths (37%) thought they had learned about the work being done by present-day scientists. Less than a third (29%) thought they had learned about the characteristics of scientists, for example describing them as smart, hardworking, or passionate, while more than a quarter (27%) thought they had learned about scientists of the past or their discoveries. One-sixth (17%) learned that scientists work together, a tenth (13%) said they hadn't learned anything, and less than one-tenth each described learning that anyone can be a scientist (5%) or shared another response (3%). Examples of students' comments about what they learned about scientists are in Table 16 on the next page.

Figure 6. Things students learned about scientists from the videos and/or film (n = 169)



Those who watched the character videos were significantly more likely to report that they learned that anyone can be a scientist compared with those who watched the content videos (9% vs 1%; Fisher exact test, $p = .03$).

The younger grade level was significantly more likely than 8th graders to report learning about work done by present-day scientists (46% vs 30%; Fisher exact test, $p = .05$).

[9] Not included in section 3.4 are 14 students who said they did not know or could not remember and seven who gave answers that were not specific to the content about scientists from the videos and/or film.

Table 16. Things students thought they learned about scientists from the videos and/or film (n = 169)

Learned about the work done by present-day scientists (37%)

- *I learned how much work it takes to make the Collider.*
- *I learned about all the ways they experiment and discover new things about the universe.*
- *…some scientist had accidents trying to make the Collider work.*
- *I learned that scientists are not just doing complicated math and trying to figure out impossible questions. They are solving interesting questions and getting real answers.*
- *Particles created the galaxy. You can simulate the galaxy formation.*

Learned about the characteristics of scientists (29%)

- *Scientists are smart people*
- *How passionate scientists are [and] how hard they work*
- *They enjoy what they're doing. It looks like it is not a job, they're just doing it for fun.*
- *That in order to be successful like those scientists we need to be curious.*
- *They make science-related jokes sometimes. They also are pretty competitive sometimes.*
- *They aren't always in lab coats mixing chemicals*

Learned about scientists of the past or their discoveries (27%)

- *One thing I learned was that some scientists died from radiation discovering and learning about radiation to help others live and survive. I also learned that only one scientist in the world has won two Nobel prizes in 2 different areas of science.*
- *That the scientist Galileo was placed under house arrest. I learned the scientists' names, there were many.*
- *I learned that a lot of the time theories made from scientists take a while to be proved right or wrong.*
- *I learned the year they were born and the year they died. I learned how they influenced modern science .*

Learned that scientists work together (17%)

- *Scientists were really cool to learn about because they work together in teams a lot*
- *One thing that I didn't know about scientists is that they work with their enemies because they want to find an answer and it can only be found by teamwork.*
- *I didn't know that scientists communicated together from different parts of the world.*

Learned that anyone can be a scientist (5%)

- *I learned that all scientists come from all types of backgrounds and genders*
- *That they span a wide range of ages and are much like normal people.*
- *I also learned that most of the time they aren't even that smart at a young age but become intelligent and become a great scientist just by taking normal classes.*

Other (3%)

- *I actually didn't know about any scientists at all, so I learned a lot about scientists*
- *That they get to narrate movies*

Image 2. Screenshot from the film of present-day scientists at the Perimeter Institute

Part 4. Impact of videos and film on interest outcomes

4.1 How students thought the videos and film affected interest in science

On average, students thought their experience with the videos and film somewhat increased their interest in science (*Mdn* = 2.0, *M* = 2.1). Table 17 shows the percentages of students who gave each rating.

Table 17. Frequency distribution of students' ratings of how the videos and film affected their interest in science (N = 190)

Did not affect 0	Increased a little 1	Increased somewhat 2	Increased moderately 3	Increased a lot 4
15%	17%	25%	26%	17%

The younger grade level felt their interest in science increased significantly more compared with the older 8th grade level (*M* = 2.4 vs 2.0; $t(165) = 2.43$, $p = .02$).

Students' ratings of statements of how SOTU media affected interest in the Collider

On a scale of 1 to 5, students rated five statements about how their experience with the SOTU videos and film affected their specific interest in the Collider. On average, students agreed that they were more interested in how the Collider can be used to do research about the universe (*Mdn* = 4.0, *M* = 3.8), learning about the tiniest particles in nature (*Mdn* = 4.0, *M* = 3.7), the different kinds of experiments and research the Collider is capable of (*Mdn* = 4.0, *M* = 3.6), and searching out information about how the collisions occur in the Collider (*Mdn* = 4.0, *M* = 3.5). They were more neutral as to the SOTU media's impact on their interest in how the Collider was built (*Mdn* = 3.0, *M* = 3.5). Table 18 shows the percentages of students who gave each rating.

Table 18. Frequency distribution of students' ratings of statements about how the videos and film affected their specific interest in the Collider (N = 190)

As a result of my experience with *Secrets of the Universe*, I am more interested in…	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
how the Collider can be used to do research about the universe.	2%	7%	29%	34%	28%
learning about the tiniest particles in nature.	3%	7%	31%	36%	24%
the different kinds of experiments and research the Collider is capable of.	4%	9%	27%	38%	21%
searching out information about how the collisions occur in the Collider.	4%	8%	35%	36%	17%
how the Collider was built.	4%	9%	37%	33%	16%

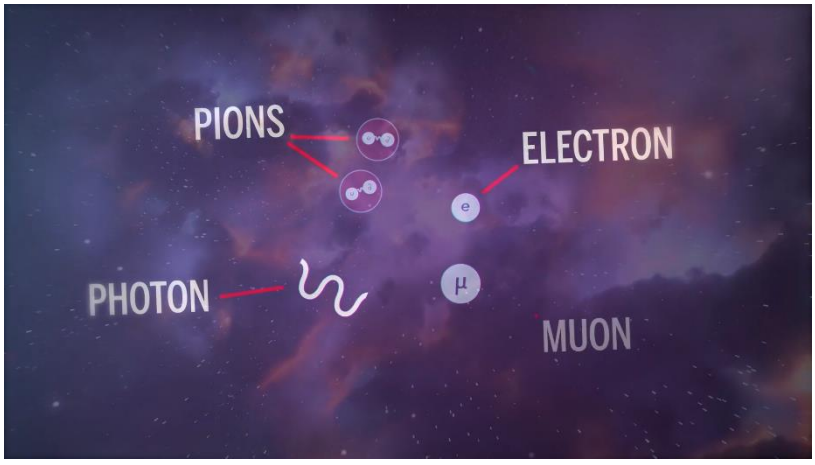
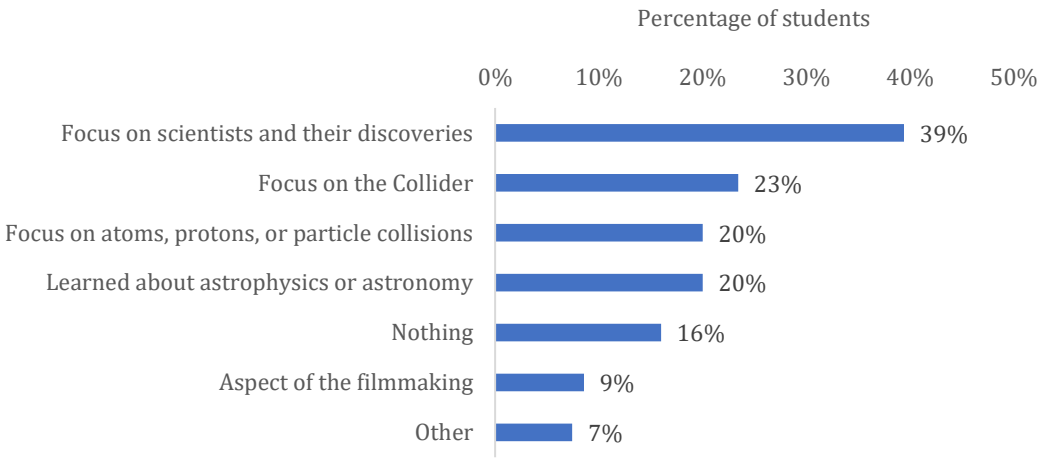


Image 3. Graphic of how LHC collisions explode matter into its tiniest components, some of which reflect particles of the early universe, from the pre-film science content video Great Machines in Science: The Large Hadron Collider

4.2 What about the videos and film affected students' interest in science

Students were asked what about the SOTU videos and film affected their interest in science. As shown in Figure 7, of those who provided answers about things that affected their interest in science[10], two-fifths (39%) pointed to the focus on scientists or their discoveries. About a fifth each mentioned the focus on the Collider (23%), the focus on atoms, protons, or particle collisions (20%), and their learning about astrophysics or astronomy (20%). One-sixth (16%) said nothing affected their interest in science, and less than a tenth each highlighted an aspect of the filmmaking (9%) or shared another response (7%). Examples of students' comments about the things that affected their interest in science are in Table 19 below and on the next page.

Figure 7. Things about the videos and/or film that affected students' interest in science (n = 175)



The younger grade level was significantly more likely than 8th graders to describe the focus on atoms, protons, or particle collisions as affecting their interest in science (29% vs 14%; Fisher exact test, p = .02).

Table 19. Things about the videos and/or film that affected students' interest in science (n = 175)

Focus on scientists and their discoveries (39%)

- *It gave me an interest in science from the past and got me thinking how it all connects*
- *I never thought of the possibility of myself working on something like this in the future, I would love to have an impact on future scientists, as past scientists have had on myself.*
- *I liked that the scientists came from different places to work on the LHC and that they end up being able to fix everything and make it work all together.*
- *[One thing] that interested that me was how hard they work.*
- *That anyone can be a scientist at a young age and that there is a lot of fun things to learn…*

Focus on the Collider (23%)

- *The Hadron Collider was a really interesting tool that I liked learning about*
- *I think the LHC's size and how it works interested me the most.*
- *The Collider was cool.*
- *One thing that affected me was when they made the 27-yard Collider around CERN. Another thing that intrigued me was when the Collider worked!*

[10] Not included in section 4.2 are five students who said they did not know or could not remember and 10 whose answers were not specific to the content of the videos and/or film.

Table 19 continued. Things about the videos and/or film that affected students' interest in science (n = 175)

Focus on atoms, protons, or particle collisions (20%)

- *The way they portrayed the science of atoms. And the way the atoms reacted when they collided.*
- *I figured out that atoms can collide and become even smaller and smaller than we ever thought.*
- *I learned more about the protons.*
- *Quarks were interesting but it was kind of confusing*
- *I loved all the different atoms they explained in the film. Made me curious which made me want to find out more. I also loved seeing how atoms work. Made me very interested in the atoms topic in science.*

Learned about astrophysics or astronomy (20%)

- *It also showed cool aspect such as the design of the universe and the big bang theory. These intrigued me somewhat.*
- *Learning about the galaxy was the most interesting thing for me.*
- *One thing that like caught my eye was about the planets, I thought that was pretty interesting.*

Aspect of the filmmaking (9%)

- *[One] thing that made science more interesting was the video. The video made it more interesting because of all the effects…*
- *One thing that affected my interest in science is the visual, pictures and videos but most of all the visuals. It's cool that science can give you such cool visuals.*
- *I like how they made the video.*

Other (7%)

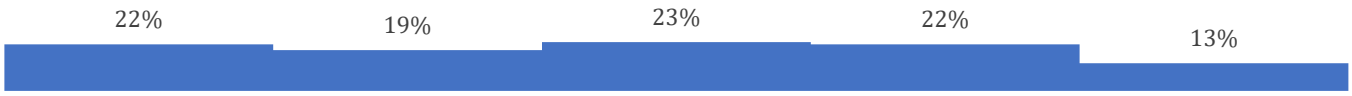
- *The math looks cool and complex*
- *Something that affected my interest in science was how many different things there are in science.*

4.3 How students thought the videos and film affected interest in scientists

On average, students thought their experience with the videos and film somewhat increased their interest in scientists (*Mdn* = 2.0, *M* = 1.8). Table 20 shows the percentages of students who gave each rating.

Table 20. Frequency distribution of students' ratings of how the videos and film affected their interest in scientists (N = 190)

Did not affect 0	Increased a little 1	Increased somewhat 2	Increased moderately 3	Increased a lot 4
22%	19%	23%	22%	13%



The younger grade level felt their interest in scientists increased significantly more compared with the older 8th grade level (*M* = 2.2 vs 1.6; *t*(160) = 3.24, *p* = .002).

Students' ratings of statements of how SOTU media affected interest in scientists and becoming a scientist

On a scale of 1 to 5, students rated five statements about how their experience with the SOTU videos and film affected their interest in scientists and becoming a scientist. On average, students agreed that they were more interested in how scientists from the past have contributed to the science of today (*Mdn* = 4.0, *M* = 3.8) and scientists and the kind of work they do (*Mdn* = 4.0, *M* = 3.6). They were neutral as to whether they were interested in learning about jobs or careers in science (*Mdn* = 3.0, *M* = 3.4), searching out more information about the scientists featured in the videos and film (*Mdn* = 3.0, *M* = 3.3), and exploring pathways they could take to become a scientist (*Mdn* = 3.0, *M* = 3.2). Table 21 shows the percentages of students who gave each rating.

Table 21. Frequency distribution of students' ratings of statements about how the videos and film affected their interest in scientists and becoming a scientist (N = 190)

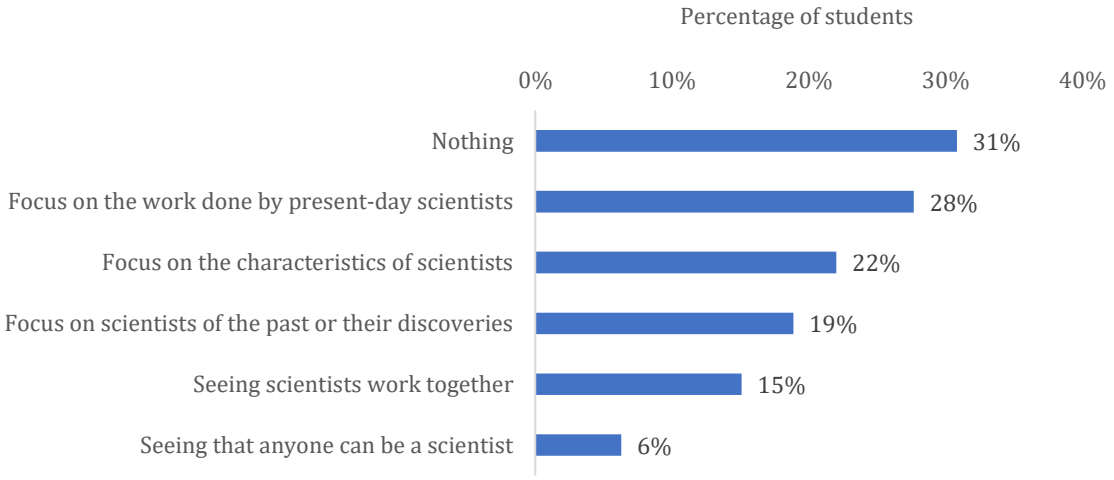
As a result of my experience with *Secrets of the Universe*, I am more interested in…	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
how scientists from the past have contributed to the science of today.	3%	7%	28%	33%	28%
scientists and the kind of work they do.	4%	6%	36%	36%	18%
learning about jobs or careers in science.	5%	11%	41%	25%	18%
searching out more information about the scientists featured in the videos and film.	5%	18%	36%	27%	14%
exploring pathways I could take to become a scientist.	6%	18%	36%	26%	13%

The younger grade level was significantly more interested compared with 8th graders in contributions of scientists from the past (*M* = 4.0 vs 3.6; $t(160) = 2.21$, $p = .03$); in scientists and the kinds of work they do (*M* = 3.8 vs 3.4; $t(166) = 2.77$, $p = .006$); and in searching out more information about those featured in the videos and film (*M* = 3.7 vs 3.0; $t(157) = 5.02$, $p = .0001$).

4.4 What about the videos and film affected students' interest in scientists

Students were asked what about the SOTU videos and film affected their interest in scientists. As shown in Figure 8, of those who provided answers about things that affected their interest in scientists[11], a third (31%) said nothing had this effect. More than a quarter (28%) pointed to the focus on work done by present-day scientists, and about a fifth each pointed to the focus on the characteristics of scientists (22%) and the focus on scientists of the past or their discoveries (19%). One-sixth (15%) said their interest was affected by seeing scientists work together, and less than one-tenth (6%) said their interest was affected by seeing that anyone can be a scientist. Examples of students' comments about the things that affected their interest in scientists are in Table 22 on the next page.

Figure 8. Things about the videos and/or film that affected students' interest in scientists (n = 159)



Significantly more 8th graders than the younger grade level said nothing affected their interest in scientists (38% vs 19%; Fisher exact test, $p = .01$). Girls were significantly more likely than boys to focus on scientists of the past or their discoveries (26% vs 9%; Fisher exact test, $p = .01$), and the younger grade level also noted this category more often than 8th graders (27% vs 13%; Fisher exact test, $p = .04$).

[11] Not included in section 4.4 are 10 students who said they did not know or could not remember and 21 who gave answers that were not specific to the content about scientists from the videos and/or film.

Table 22. Things about the videos and/or film that affected students' interest in scientists (n = 159)

Focus on the work done by present-day scientists (28%)

- *Another thing about the film that affected my interest in scientists was how they came up with Collider device and why/how they are inspired to make it.*
- *How cool science can create cool technology to learn more about science.*
- *That scientists have a hard job at trying to figure out how atoms work.*
- *I am more interested in the info about the scientists in the film. I am more interested in the kind of work scientists can do.*
- *Scientists are discovering things that people from 100 years ago would never dream of and discovering places so hot that atoms can't exist.*

Focus on the characteristics of scientists (22%)

- *How they are extremely smart*
- *I saw how much they work and try their best. I also know how much they try their best to build or get it right.*
- *Seeing them work so hard and seeing all their work their doing makes me feel so interested in it.*
- *How they were really passionate about their work and found it fun*
- *It affected me about how they want to help others. How they want to find answers for anything.*

Focus on scientists of the past or their discoveries (19%)

- *Two things that affected my interest in scientists were how Louis Pasteur discovered tiny creatures in some water, and how Edwin Hubble led to the creation of the Hubble Space Telescope.*
- *… learning about what past scientists have discovered and how they discovered what they did.*
- *Another thing that affected my interest in scientists is that without scientists from the past, modern scientists would not be able to do anything.*
- *I was interested in how the scientists who lived a long time ago helped make the science of today possible.*

Seeing scientists work together (15%)

- *One thing that affected my interest in scientists is that it takes a team of them to make accomplish something.*
- *How well they worked together*
- *It increased my interest in scientists to see how… they work with lots of different people around the world.*

Seeing that anyone can be a scientist (6%)

- *One thing that affected my interest in them is how anybody can be a scientist from any background and kinda technically age.*
- *Another thing that affected my interest [in] scientists was when it explained Marie Curie's life because I thought it was really cool that a female like me could affect so many people's lives in a good way.*
- *It made me think that I could become a scientist and learn about space. It made me think that maybe I can discover something new in space and affect the world and change it.*

Phase 2: Further exploration of girls' experience with the *Secrets of the Universe* science characters

Phase 2 of the summative evaluation was designed to answer two questions: *What is the impact of the science characters in the videos and film on girls' thoughts about scientists? What is their opinion of the effectiveness of the characters as role models in encouraging their interest in science?*

Method

Evaluation Design

Phase 2 of the summative evaluation implemented a more in-depth exploration of middle school girls' experience with the SOTU videos and film – and, in particular, the science characters featured in each media format. As noted in the Introduction, this supplemental evaluation was conducted as middle school girls were identified as a key target audience in the NSF proposal. A set of conversation groups were conducted at MOSAC with girls who viewed the science character pre-film videos at home prior to watching the SOTU film as part of Phase 1.

Participants

Recruitment

The 20 girls who participated in the Phase 2 conversation groups learned about the evaluation opportunity through an information letter distributed by greater Sacramento teachers and field researchers during the summer of 2022. The letter contained comparable information to that teachers shared with their female students and parent/guardians in Phase 1 (see page 12). Additionally the letter described the purpose of the conversation groups; reviewed benefits and possible minimal risks of participating; and reviewed confidentiality of information with an explanation that group sessions would be audio recorded to allow for transcription of responses and then the recording destroyed. The letter also included a link to online consent and assent forms for girls to share and complete with their parents/guardians with the evaluation team coordinating the return of permission forms. Those who submitted forms were scheduled to participate in the session date provided. The girls received honoraria for participating and were given the additional incentive that they could spend time at MOSAC visiting the museum after their SOTU evaluation participation.

The final student sample analyzed in Phase 2 (N = 20) includes girls who completed all parts of the study design: those who watched and recalled the science character pre-film small screen videos; traveled to MOSAC to view the giant screen SOTU film and visit the museum exhibits; completed all post-survey questions on the same day of the museum field trip; and participated in one of three conversation groups.

Demographic and background information

Table 23 presents demographic and background information for the 20 middle school girls who completed the full Phase 2 procedure. All students viewed the pre-film science character videos. The sample ranged in age from 11 to 13, more than half were in the 6th grade, and half identified as multiracial.

Table 23. Students' demographic and background information

Demographic/ background factor	Categories	Pre-film science character viewers (N = 20)
Gender	Female	100%
Age group	Age range	11-13
	Mean	11.9
Grade	5th	0%
	6th	60%
	7th	15%
	8th	25%
Racial/ethnic Group	African American/Black	10%
	Asian	15%
	Multiracial	50%
	White	15%

Procedure

Via a Vimeo link, the girls viewed on their home computers the science character videos (illustrated in Table 3, page 14). Within the next 1-2 days at MOSAC, girls participated in one of three conversation groups after watching the film and completing the post-viewing survey. Survey completion and all three sessions were held in a classroom located in the museum and were led by the same evaluation moderator and assistant. The moderator informed participants: that their participation was voluntary; that only their opinion mattered and there were no right or wrong answers; that their names and identities would be protected in the reporting; and that, as with the post-viewing survey, the conversation groups were made possible with support from the National Science Foundation. The discussion sessions ran approximately 50-60 minutes, which included time for settling participants into the room, introductions, an ice-breaker activity, discussion, and wrap-up.

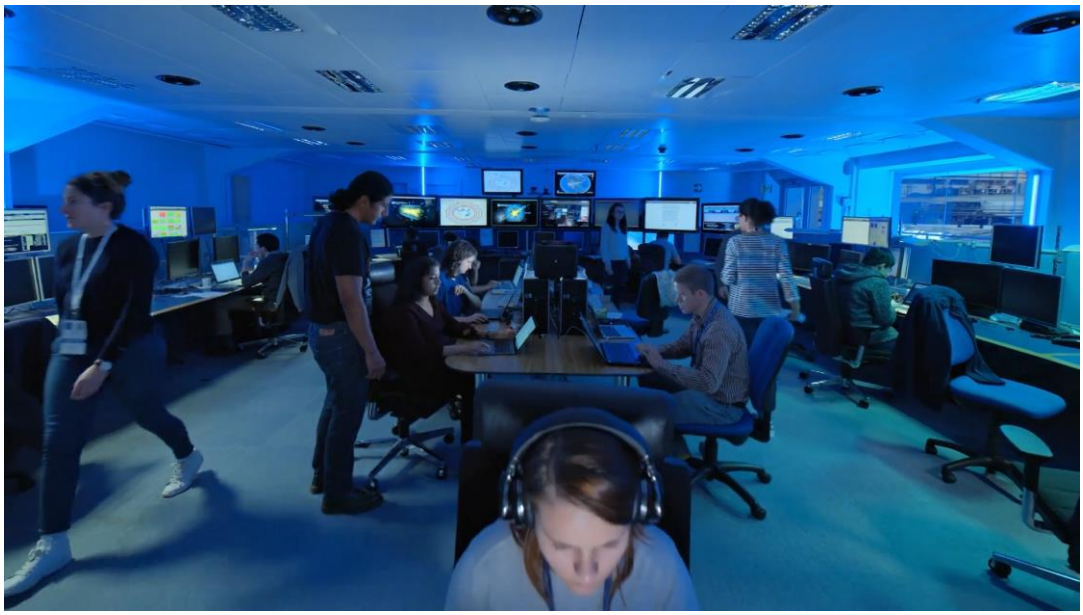
The discussion protocol included a set of six open-ended questions with facilitating probes, as shown in the final protocol in Appendix 2. Two key question areas were explored in the discussions: 1) The effect of the pre-film videos and film on girls' thoughts of scientists and seeing themselves as science characters in the film, and 2) their perceptions of role models in life, science, and SOTU media. The findings are described, respectively, in Parts 1 and 2 under Results.

Analysis

After the conversation groups were transcribed, content analyses were performed on the qualitative data generated in the open-ended questions. The analysis drew on gender differences that emerged in the Phase 1 findings and considered the 2019 front-end review work and fine-cut evaluation findings described in the Introduction on page 9. As such, the analyses were deductive, drawing on the project's goals, objectives, and prior work, and inductive, looking for overall themes, keywords, and key phrases. In the reporting, note that as girls' responses did not typically differentiate between the two types of media (pre-film videos or film), any distinctions are pointed out where applicable.

Results

Part 1: Impact of the *Secrets of the Universe* science character videos and film on girls' thoughts about scientists and seeing themselves as onscreen science characters

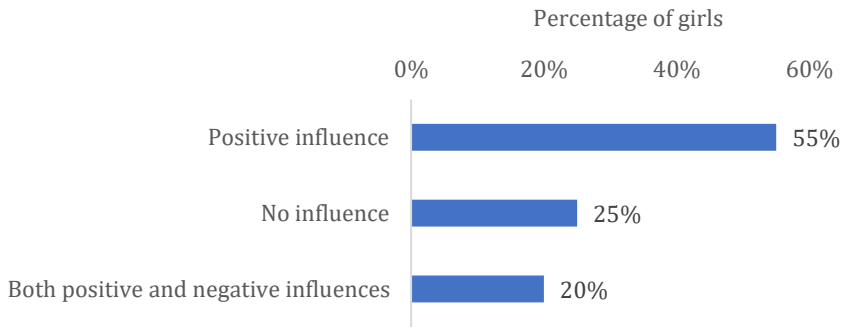


1.1 Whether and how girls perceived that the pre-film videos or film influenced how they thought of scientists

Leading into the conversation groups, girls were first asked to consider a general question about the impact of their experience with the SOTU pre-film videos and film on their perceptions of scientists: *Do you feel that the videos or film changed how you think of scientists?* This question was followed by probes to help understand how the SOTU media did or did not change their thinking. Those who indicated positive changes were asked: *How did watching the videos or film change how you think of scientists?* Those who indicated no changes or negative changes were asked: *Why do you think that the videos or film did not change how you think of scientists?*

As shown in Figure 9, just over half (55%) of the 20 girls indicated that the SOTU media positively changed their thoughts about scientists, while one-quarter (25%) felt their thoughts hadn't changed, and one-fifth (20%) indicated their thoughts changed in both positive and negative ways. Examples of girls' comments are in Table 24 on the next page.

Figure 9. Effects of the videos and film on girls' thoughts about scientists (N = 20)



Positively influenced thoughts about scientists

Just over half (55%) of the girls reported that the pre-film character videos and/or film positively changed how they thought of scientists. Not quite one-third each indicated they felt a greater appreciation or understanding of the impact that scientists' work has on other people or the world at large (30%), how hard scientists work (30%), and/or how scientists think or do their work (30%). One-fifth each pointed to having a greater appreciation or awareness for the passion scientists bring to their work (20%), how the scientists of today build on the scientists of the past (20%), and/or the importance of collaboration among scientists (20%). Smaller numbers learned about the challenges of scientific work (15%) and/or that scientists come from diverse backgrounds (10%).

No influence on thoughts about scientists

One-quarter (25%) of the girls felt the SOTU media did not affect how they thought about scientists, most of whom did not elaborate as to why.

Positively and negatively influenced thoughts about scientists

One-fifth (20%) of the girls mentioned ways that the SOTU media positively influenced their thinking about scientists while also mentioning one way they were negatively impacted, with each girl pointing to the potential of dangerous consequences, including dangers posed to the scientists themselves, as in the radiation exposure Marie Curie suffered, and/or through the scientists' projects or experiments having unintended negative impacts, as cautioned by Dr. Manuel Calderón de la Barca Sánchez when describing the potential for explosions with the Collider.

Table 24. How girls indicated the SOTU media influenced how they thought about scientists (N = 20)

Positively influenced thoughts about scientists (55%)

- *The scientists impacted me more because I didn't know that much about scientists, but then when I saw the scientists were doing all these things, I figured out how much impact they have on our real world, like how they help doctors and how all the atoms come together like that.*
- *Yes, it did change the way I see scientists, I mean, I already knew they work really hard…but it made me see that they're really passionate about their work. Oh, there's one more thing...it really seems like a lot more difficult than what it seems.*
- *The way that I saw how the scientists impacted me was the collaboration. Like normally back then, when they would like introduce Charles Darwin or Albert Einstein, they worked solo. But the film that we watched really showed and proved that scientists need to work together, especially when they want to make a huge device… just the evolution of science itself really just shows the importance of collaboration versus one scientist working alone, so yeah, how they worked together. It could just make a huge project to really help future citizens or generations.*
- *I thought it was good how hard the scientists worked and how it really mattered what they did, and if they did it right too. I also liked how it showed anyone can be a science person no matter who you are, and that skin color or whatever doesn't matter.*
- *I really like how it really immersed me in the thinking of the scientists and what they did and how they recorded things… How much they work together is also important because if they're making a big project, they have to work together. Like the film said that some countries are working together that traditionally hate each other. It's nice to think about that because the whole world has a part of making science, and of making past science come to life.*

No influence on thoughts about scientists (25%)

- *It really didn't change for me. I feel I knew about scientists already.*

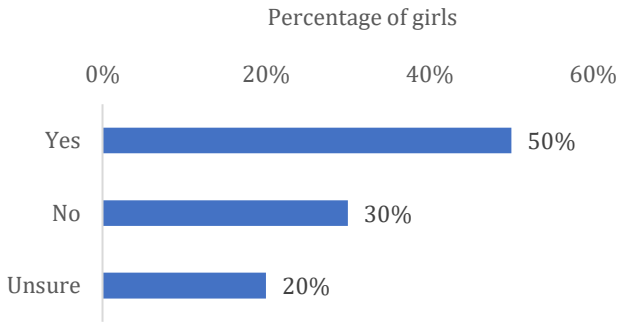
Positively and negatively influenced thoughts about scientists (20%)

- *In a way, well, it kind of changed the way I think of scientists. Like I started to think of them as actual people. I mean, I know they are actual people, but like the way people described and explained things, they explained things well. I mean, they're kind of like holy in a way, but I also see them kind of as like people who are just trying to possibly just understand things or just have some curiosity, or they're trying to solve something like a problem, like in their village. Or it could be something like with the germs, it could have been something like that. Well it's just analogy or an example, but yeah, I just kind of see them as like regular people trying to like experiment things and create solutions or understand things to more like help other people. Like, they might say "Wash your hands because this is what is gonna happen if you don't and everybody else is gonna get sick." Just like stuff like that.*
  Can I say something else? I mean…it kind of impacted me negatively because I already kind of thought about this before, but like how scientists when they're experimenting a lot, it can also like, cause a problem. Like with people in the environment getting hurt from a chemical spill or if you have lots of animals lost and how they may try to replace a certain species, and then…it can literally put the world at stake, so things like that.

1.2 Whether and how girls could see themselves in any of the science character roles pictured onscreen in the pre-film videos or film

As part of the discussion about the film's science characters, girls were asked: *Could you see yourself in any of the scientist roles pictured onscreen in the videos or film? Why or why not?* As detailed below and shown in Figure 10, half (50%) of the girls could see themselves in one or more of the scientist roles pictured on screen, typically as a graduate student, and most often as Dr. Santona Tuli. Not quite one-third (30%) said that they could not see themselves in such a role, most often because it didn't occur to them while viewing, whereas one-fifth (20%) indicated they were unsure because they saw the job of a scientist as being too difficult or time consuming or because they had little interest in science.

Figure 10. Whether girls could see themselves in any of the scientist roles pictured onscreen (N = 20)



<u>Could see themselves in a science character role</u>

Half (50%) of the girls said they could see themselves in one or more of the scientist roles pictured onscreen, nine of whom focused on the featured graduate students, with six pointing specifically to Dr. Santona Tuli, pictured in the image below on the right. Most often girls talked about being to *relate to her*, being drawn to how *she looked* and/or *talked*, recognizing that she seemed *most like* them, or liking how she seemed *down to earth*. One girl who pointed to Dr. Tuli also pointed to seeing herself as Marie Curie but didn't elaborate as to why.

Images 4 and 5. Images showing graduate students featured in the SOTU film

An excerpt from one group's discussion about the graduate students and Dr. Tuli, in particular, follows in Table 25 on the next page. Note that all of the girls were from Sacramento, CA, thus UC Davis was familiar to them.

Table 25. Excerpt from girls' conversation group about how they could see themselves in a science character role onscreen (n = 6)

- *I think maybe I could picture myself maybe as one of the graduate students, because I like science and I like to research and do experiments. So maybe I could see myself doing that.*
- *I agree, the woman from Davis, was it? I felt I could relate to her, how she looked, what she said about her younger self. She made it seem like the path to get to where she was, like it was possible with work.*
- *Yeah. And how they were working on the Collider and, and, um, fixing everything up. Okay. And researching, I can probably see myself that, that role.*
- *I also think the girl from Davis would be someone I see myself as. I liked how she just talked and made it seem real.*
- *I feel the same way, if I was going to see myself as anyone in the film it would be her. She seemed really down to earth if you know what I mean and I like how she made us see her from her younger person self.*
- *I'm surprised that they, that this film was based on UC Davis graduate students… just to see that certain students from UC were able to have the opportunity to be part of this film is cool because eventually in years and years and later, students that are in like elementary school, for example, when they get to middle or high school, they might watch this film and be like, wow, like 10 years ago, or yeah, 10 years ago, graduate students from UC Davis had the opportunity to be part of this film and it's life changing.*

Could not see themselves in a science character role

Nearly one-third (30%) of the girls said that they could not see themselves in one of the scientist roles featured in the SOTU media, four of whom indicated it didn't occur to them. Of the remaining two girls, one said she wasn't sure why not, and one elaborated that she perceived that the job of scientist seemed c*omplicated*, *prestigious,* and *too much*, and she preferred jobs that seemed more *fun* or *chill*, as shown in the comments in Table 26.

Table 26. Why girls didn't see themselves in a science character role onscreen (n = 6)

- *I didn't see myself in the film, I didn't think about it*
- *I didn't either (think about it)*
- *I personally would not see myself as a scientist, only because I am just not the kind of person that would do like that kind of prestigious job. I like more fun and not getting messy…more like chill, I guess, jobs that don't seem too much too me, jobs that won't like break you…the film was like very interesting and it made me like, want to learn more about science. But, I just feel like being a scientist is a, like, very, well, not just complicated, but very prestigious cuz you have to make sure like you do everything right.*

Unsure whether they could see themselves in a science character role

Finally, one-fifth (20%) of the girls indicated they were unsure whether they could see themselves in a science character role onscreen, elaborating that they saw the job of a scientist being some combination of *difficult, hard, taking a lot of time, and/*or requiring *doing all the steps right,* with a couple of girls further expressing that they didn't feel *passionate about or invested* in science, as shown in the comments in Table 27.

Table 27. Why girls were unsure of seeing themselves in a science character role onscreen (n = 4)

- *Well, I would think that anyone could become a scientist.. I want to, but at the same time, it seems very difficult. Like it's not an easy job. And I don't know, I'm kind of like, I don't wanna say I'm kind of dumb, no, that's not a good thing to say, but yeah, it does seem really difficult. I would be interested though because it seems really interesting. It's just hard because you need to be passionate about your work and there's gonna be days where it's gonna seem very hard and that you can't do anything, but, you know, that's how everything is.*
- *I'm not sure I could really see myself in the film. I admired what all of the scientists were doing, I just didn't see myself being one of them if that makes sense. I kind of agree that it seemed like a lot, or it takes a lot to be successful and be sure you are doing all the steps right.*
- *Possibly, possibly, hm, I don't know. Probably not. Cause I mean, I'm interested in science but I'm not super duper invested like that. I used to wanna be a scientist, like a doctor and everything, but, you know, as time goes on, I get more passionate about beautification like cosmetology. I mean, that's also like a form of science, but you know, it's not something that people are really like invested in. Science takes a lot of time. So possibly.*

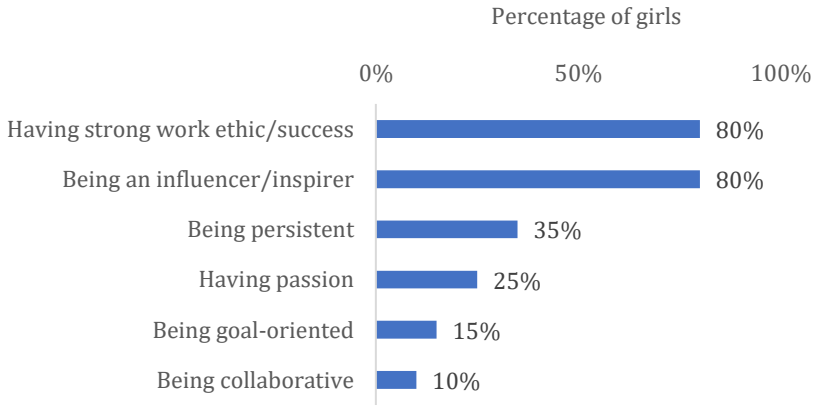
Part 2: Girls' perceptions of role models in their lives, in the field of science, and in the *Secrets of the Universe* pre-film science character videos and film

2.1 What the term 'role model' means to girls and who they see as a role model in their lives and why

To segue into the conversation about girls' perceptions of role models in science, girls were first asked to reflect on what the term 'role model' meant to them, by taking a few minutes to write down two or three words that came to mind when they heard the term. The discussion then focused on the following question: *Can you think of anyone in your life or in the media who is a role model for you? If yes, please explain how they are a role model for you.* Coding of the descriptions of a 'role model' drew from the words girls were asked to generate as they described a role model and also included their ideas communicated through their descriptions of the people they identified as their personal role models.

As shown in Figure 11, two major themes emerged in the girls' characterizations of role models: having a strong work ethic/success, represented by working hard, being responsible, competent and/or successful (80%), and being an influencer/inspirer either through their support or their relatability (80%). Four additional themes appeared somewhat less frequently: being persistent (35%), passionate (25%), goal-oriented (15%), and collaborative (10%).

Figure 11. Girls' characterizations of role models (N = 20)



Of the 20 girls, just over half (55%) identified family members as their personal role model, one-tenth (10%) identified people in the media (Sally Ride and Michelle Obama), and one person (5%) identified themselves. Just over one-third (35%) did not identify anyone but did describe role model attributes.

Examples of girls' comments about the characteristics of role models are in Table 28 below.

Table 28. Girls' characterizations of role models (N = 20)

Role models have strong work ethic/success (80%)

- *I think a role model is a person who has responsibilities and good actions and they work hard and are into their family. I think my mom is, um, one of my role models because she's very like passionate about her job and she takes it very seriously, sometimes too seriously. …And I think when I'm older, I want to have her maturity…I think it's awesome.*
- *Well, they kind of show it with their achievements and then they also say it. So they're like encouraging them, like you can do this too. Anyone can do it.*
- *Yeah, they [parents] work really hard. Like literally they're always trying to give us the very best, they work really hard to make our childhood good, yeah, they're always working.*
- *I think a role model means to work hard setting good examples for younger kids… and also responsibilities.*

Role models are influencers/inspire (80%)

- *When I think of a role model I think of the words influencers and supporting. A role model in my life, is my grandma because she went to school and got her degree and she also owned her own business.*
- *I can't think of someone right now, but I think they would need to be someone who has a good example of something I want to be good at it. That person would be able to show me like how to do what I'd want to do, and I think they would probably look like me or be someone I could relate to.*
- *I think my role model would be Sally Ride because it's so amazing how she was the first woman to go in space and she really benefitted and showed women that really wanted to be part of the science how to do that and how to be part of it, and how everything worked, and that you can do it.*
- *When I think of a role model it is someone who sets an example and someone people admire and want to follow…*

Role models persist, stand up for self/others (35%)

- *Like standing up for themselves and setting an example for like younger kids than them. Standing up for what they believe.*
- *I think a role model, like should not be afraid to be themselves and awesome, but is passionate and like a hard worker with a good worth ethic.*
- *Someone who stands up for yourself and other people and younger kids. Someone who sets a good example. I feel like my godsister is a role model to me and my sister, because she's actually in the army…I like how her team fights very hard for our country and traveling and going different type of places to make sure people are okay and safe.*

Role models are passionate/inspiring (25%)

- *I think a role model should be (reading from list) courageous, kind, nice, encouraging, successful, open-minded, a leader, independent, and have self-love. So really, I think my role model would be Sally Ride because it's so amazing how she was the first woman to go in space and she really benefitted and showed women that really wanted to be part of the science how to do that and how to be part of it, and how everything worked, and that you can do it.*
- *My mom, cause she's worked for a lot of stuff on her own. I admire that part. To me a role model is someone that inspires someone. My mom is mine because she is very successful.*

Role models are goal-oriented (15%)

- *And especially, uh, my mom's sister, I always kinda looked up to her because she was kind of like everything I wanted to be in a way, like how she travels and does stuff. And how she's organized in a way, how she puts stuff in order, like that. …she keeps going, especially when it comes to stuff that she likes, like her goals, she gets them done the majority of the time. So I see her accomplishing her goals and I'm like, you know, I'm like, wow."*

Role models are collaborators (10%)

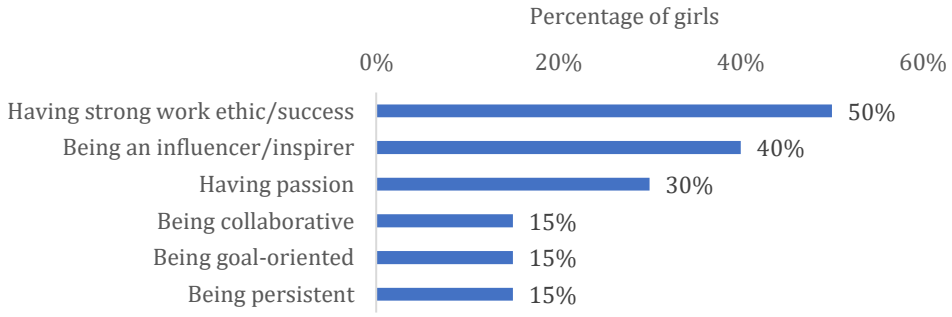
- *Like working together, working together with teamwork.*

2.2 Role model characteristics girls see as important to encouraging their interest in science

After discussing what the term role model means to girls, they were then asked to consider the idea of a role model in science, as follows: *Let us now consider role models in the area of science. What characteristics would make a role model most effective in encouraging your interest in science?* Responses from all 20 girls were coded, using the same categories as in Section 2.1, which focused on role models more generally.

As shown in Figure 12, three major themes emerged: having a strong work ethic/success (50%), being an influencer/inspirer either through support and communication or their relatability (40%) and having passion (30%). Three additional themes appeared somewhat less frequently: being collaborative (15%), goal-oriented (15%), and persistent (15%).

Figure 12. Role model characteristics girls saw as important to encouraging their interest in science (N = 20)



Examples of girls' comments about the characteristics of role models to encourage science interest are in Table 29 below and on the next page.

Table 29. Role model characteristics girls saw as important to encouraging their interest in science (N = 20)

Science role models have strong work ethic/success (50%)

- *And I think you should be like responsible. … like sharing responsibility and always working hard and being very proud and passionate and not ashamed of being who you are as a scientist.*
- *They would need to be good at science and be able to show how they got to where they are, what they did, what they had to deal with, stuff like that.*
- *I also don't have a specific scientist, but because of science and because of the scientists being ready to learn and like explore, and have that, like adrenaline rush of being excited to find the results of their research, I find that part exciting. For me, I wanna be a surgeon. And I know that takes up a lot of work. And part of that is because of being well driven and all that. I can see others working hard and succeeding and that motivates me.*

Science role models are influencers/inspire (40%)

- *To me a science role model is someone that has a strong mind and they put a lot of effort into what they do, into small and big things. Marie Curie is my role model because she really tried. And when she tried, she did want to work hard and she worked as a chemist and oh what is it called, not a psychologist, it was a physicist. Yes. So she won two Noble Peace Prizes for doing the things she did. And she was the mother of science cuz she helped all of us understand what science is and the base of science and how to navigate through science and see the problems of science, and also how we can solve them and see how science helps.*
- *I think they would need to be successful at science and would be able to influence how future generations so science.*
- *I think I would like to see the person being a leader in their lifetime. Being a leader in their area is important.*

Table 29 continued. Role model characteristics girls saw as important to encouraging their interest in science (N = 20)

Science role models are passionate (30%)

- *Someone very passionate and enthusiastic about their work. Someone who's really into their research. They like talking about it to people. sharing their ideas constantly.*
- *I also think they should be like proud of their work and not ashamed of it. …focusing on one thing so they can put their all into it, like just all of their effort into that so they can be the best that they can be at what they do.*
- *Being passionate about like what they do and believing in what they do.*

Science role models are collaborative (15%),

- *They need to be good team members too. Like I mean show how they work together to solve problems.*

Science role models are goal-oriented (15%)

- *I think Galileo's kind of like a role model to me because when he looked through that telescope and he saw what he saw, and he like had ideas but nobody really believed him. Even though he was living on and proven to be right later, no one really believed him…he still kept believing and he didn't let going with the crowd stop him, and he ended up being right and he was correct. Sticking with it when no one else had his back, believing it when nobody else did and kind of sticking with that. To me a science role model is someone that has a strong goal and they put a lot of effort into it even if they don't accomplish it or people don't see it at the time.*

Science role models are persistent (15%)

- *Oh, just one more thing. Like if they make mistakes, they're not gonna like, get fully upset at it. Like you can get upset, but like take it as a learning experience so that you won't do it again in the future.*

2.3 Whether and how girls perceived that the science characters featured in the pre-film videos or film were effective or ineffective role models in encouraging their interest in science

Girls were shown a collage of pictures (shown in Image 6) to remind them of some of the science characters that were shown in the videos they watched at home and in the film at MOSAC, including the scientists doing work at the Collider, the young scientists on the team from UC Davis, and the historical scientists from the past. They were then asked: *Think back to the characteristics of an effective science role model that we just talked about. In what ways were any of the scientists you saw effective role models in encouraging your interest in science? In what ways were any of these scientists not effective role models?*

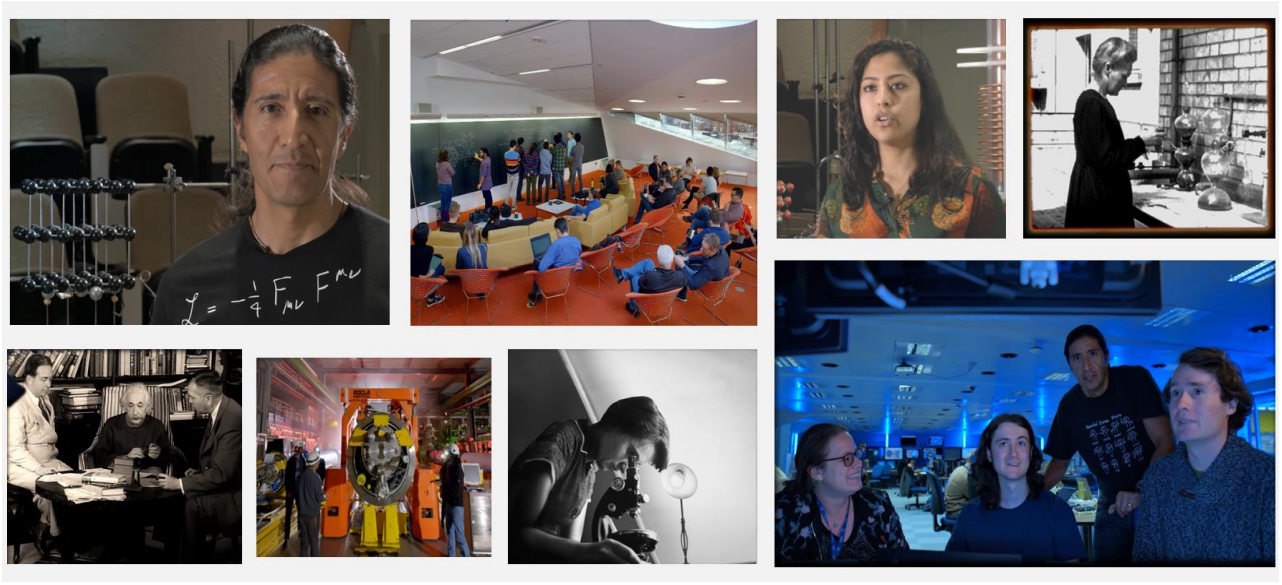
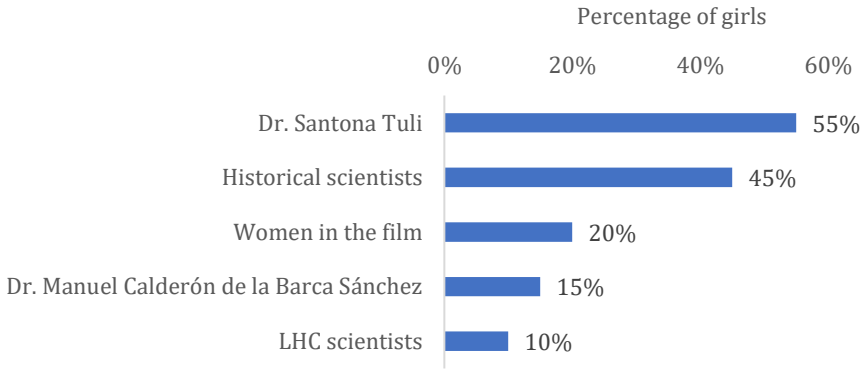


Image 6. Collage of pictures used in the Phase 2 conversation groups, showing different past and present scientists featured in the SOTU media

Of the 20 girls, more than four-fifths (85%) said one or more scientists from the SOTU media were effective role models in encouraging their interest in science. One-sixth(15%) did not identify a scientist role model, one girl did not respond (5%), and one-tenth (10%) indicated that they didn't see the scientists as role models, with one saying, "*The scientists were not really role models for me but they were working together even though they had different genders and races and were from different places*" and the other explaining, "*I'm just really not into science. I don't really know what I'd need to see to change my mind. It would have to be over the top, like the ability to time travel or do something I could imagine in my dreams.*"

As detailed below and shown in Figure 13, just over half (55%) of the girls pointed to Dr. Santona Tuli as an effective role model. Just under half (45%) focused on historical scientists. One-fifth (20%) talked about the portrayal of women in general. One-sixth (15%) pointed to Dr. Manuel Calderón de la Barca Sánchez, and one-tenth (10%) discussed the scientists working at the LHC.

Figure 13. Science characters from the videos and film that girls perceived as effective role models (N = 20)



Dr. Santona Tuli

More than half (55%) of the girls identified Dr. Tuli as an effective role model. Just over one-third (35%) described her effectiveness in terms of her being inspirational/influential. Just under one-third (30%) resonated with her detailed stories about when she was 12 years old. Smaller numbers of girls each said that they appreciated her being young (15%), being a woman of color (10%), and having passion (10%). One-tenth (10%) identified her as an effective role model but thought the SOTU media could have included more about her background.

Historical scientists

Just under half (45%) of the girls identified historical scientists as effective role models, with one-fifth (20%) highlighting the importance historical figures have on today's world. A few mentioned specific scientists, including Marie Curie (15%) or Galileo (5%).

Women's portrayal in the film

One-fifth (20%) of the girls identified women's portrayal in the film as effective with one-tenth (10%) citing work ethic and one each citing passion (5%) and the need for greater representation of women in STEM (5%).

Dr. Manuel Calderón de la Barca Sánchez

One-sixth (15%) of the girls identified Dr. Manuel Calderón de la Barca Sánchez as an effective role model. Each of these girls referenced his passion and one called out his collaborative nature and commitment to hard work.

LHC scientists

One-sixth (15%) of the girls identified the LHC scientists working on the Collider, with each noting the hard work and commitment involved.

Examples of girls' comments about the characters from the videos and film that girls identified as effective role models are in Table 30 below.

Table 30. Science characters from the videos and film that girls identified as effective role models (N = 20)

Dr. Santona Tuli (55%)

- *I also liked how the girl at UC Davis, how she was like really young, but she already had like a lot of goals. She was working hard. She had goals. All of that. And so yeah, she's still young and she's still working toward her goals but also already doing the work.*
- *I would agree that the girl from Davis was interesting to watch, she caught my attention as she seemed honest and proud of herself. She inspired me because when she was younger she had a dream and followed her dream and now she is successful and she's working at her dream job.*
- *I like what she said, she did seem to be proud like she said, like, I liked the patting on the back part of what she said. That was cool. She had darker skin like me and it showed well, she showed that that doesn't matter.*
- *Me too, I felt like she was the most like me and I could see looking up to her and learning more from her. She kinda of spoke from the heart…*

Historical scientists (45%)

- *I was also thinking about them [scientists from past]…like they started it out so that others can continue it and expand it.*
- *I think they [women scientists]were quite effective because I forget her name [Marie Curie], but she was a past scientist and she won, um, like prizes for chemistry and physics. And I think that's like really cool. And it's something that I don't think much people like touch on and like give as much, [recognition].*
- *Yes. It's Marie Curie and I feel like people don't like, like they don't talk as much as about like girl scientists as they do about the boy scientists.*
- *There was another person who I thought was a role model she was responsible for the discovery of radiation. I'm unsure of her name from the video. I've always loved science and learning about her in the film helped me become more interested. Other than them, it seems like science founders are all men and not many women.*
- *I think Galileo was effective as he showed what he was willing to do and not give up even though he spent his life, or a lot of it in jail.*

Women's portrayal in the film (20%)

- *Yeah, working really hard and like what [another girl] said. How, like they're passionate about their work. And like, sometimes it's just being fun. It is fun for them, but what [she] said, how they're being passionate about their work and not being like all bored all the time, they're actually putting effort in it and being passionate about their job and what they do.*
- *I think it [showing women scientists] helps like young ladies or young women cuz most of the time, like sometimes girls will feel like they're not eligible to be like something important, like a scientist. And I think they can really inspire young girls to do what they're passionate about or like, if they want to pursue science, all that. You know, it really can inspire them.*

Dr. Manuel Calderón de la Barca Sánchez (15%)

- *And it's like, it's really cool for how people are super passionate about the job and like what the things that they do. And basically what she (another girl in the group) said as well about being proud.*
- *Yeah. I forgot his name, but he had like long hair, Manuel, Manual? Yeah. He was, he really stood out to me cause he was very very passionate to me. He was always talking about his work to what others and sharing ideas and overall it seems like he's proud of his works, which, which is a good thing.*

LHC scientists (10%)

- *And this is not just one person, but the people that helped build a Collider I thought, um, they really interest me in science because like the Collider, like it took so much effort and it's not like an easy thing. Especially to like, keep up with and like keep running. So that's something that was really like interesting to me.*
- *I did like the teamwork part, how they worked hard together from a lot of different places to make the collider thing work.*

2.4 How girls would change or add to the portrayal of women scientists in the pre-film videos and film to make them better role models for them and other girls their age

Finally, to conclude the discussion of science role models, girls were invited to consider whether they would change or add to the women scientist portrayals in the SOTU media, as follows: *Think about how the women scientists were presented in the videos and films, the settings they were in, what they were doing, and what you learned about them. Is there anything you would change or add to their portrayal to make them better role models for you and other girls your age? If yes, what would you change or add?*

Nine of the 20 girls (45%) suggested changes or additions to the portrayal of women scientists. As detailed below, three main suggestions emerged, including the addition of more in-depth knowledge about the women scientists' backgrounds and experiences leading to their careers; an increase in the number of women represented in the video; and more visual representations of women at work.

Add more information about the women scientists' backgrounds

All nine girls recommended more in-depth knowledge of the women scientists' backgrounds, experiences, achievements, and/or hardships in general, with two girls wanting more information about Dr. Santona Tuli specifically.

Increase number of women represented onscreen

Four of the girls explicitly indicated a desire to see more women in the film, with one highlighting the desire for also seeing younger scientists represented.

Include more visual representations of scientists at work

Three girls would have liked to see more visual representation of the scientists at work, for example being actively engaged with (versus shown looking at) their computers, or perhaps working outside the 'lab' and instead in space, given that the project is called *Secrets of the Universe*.

Examples of girls' comments about how they would change or add to portrayals of the science role models in the videos and film are in Table 31 below and on the next page.

Table 31. How girls would change or add to portrayals of science role models in the videos and film (n = 9)

Add more information about the women scientists' backgrounds (9)

- *I definitely would want to see like young students, kind of like how they got into it, because they didn't really show that many young people and how they were inspiring. Like I wish they would kind of just show more young people in their backgrounds to show that like, we could do that. Cause you mostly see old people, or like middle aged or people from history. You don't really see young scientists that often…. Like definitely like people college age or graduate school who have made it or are making it, and then have them say kind of like how they got there, like what happened in middle school to them? How did they do in high school…and examples of like, maybe when things didn't always go, right. Like some people maybe weren't always into math or science, but then something kind of got them interested in them.*
- *I do wanna see like a little more background on them. Like I wanna know more about them. You know?*
- *I think that [examples of when things didn't go right] would definitely helped like, maybe something happened in that made them change their perspective on the way they view math and science and stuff.*
- *I feel like [Dr. Tuli] did a lot of the talking about what they were doing, but I don't feel like they went really too deep, like into her background, like what she did, like how she made it. But I thought it was really cool. She was still quite young, so knowing that much about science and how things in the universe worked was really cool.*
- *I also do agree with [another participant] about like how I wish to kind of talk a bit more about [Dr. Tuli's] background and stuff. Yeah, what classes [she] took or where she lived or like the influence of parents or friends, that kind of thing. I think that would definitely helped like, maybe something happened in that made them change their perspective on the way they view math and science and stuff.*

Table 31 continued. How girls would change or add to portrayals of science role models in the videos and film (n = 9)

Increase number of women represented onscreen (4)

- *I would like want to see like way more women scientists in the past. I bet there are a lot more I don't know about. So I'd love to see like recognition to them, even, even if they didn't do something humongous. Um, I would also like to see Santona like have like a bigger part and say more stuff.*
- *I feel like their [women scientists], uh, presence was good, but I would like to see maybe. More, uh, woman scientists in the film maybe, and also, uh, maybe a little bit more presence for Santona. Yeah, I like what she said and I would be interested to know what she was actually doing there.*
- *I would also like, um, I really would like if they had a whole IMAX movie featuring all women scientists. Because they're a really big part of our society.*

Include more visual representations of scientists at work (3)

- *I'm not really that interested in science, but I really like learning about it. And I thought that, um, something that helped make me wanna learn more about it, like in the film was definitely the pictures of how the atoms and molecules work, how the Collider works. Maybe seeing more pictures of them [women scientists] doing something with computers if that is what they use instead of just like showing them at computers.*
- *One thing I wish they did have is that even though atoms are great, they really talked all about atoms, but they said the secrets of the universe, the universe has a lot of different parts, but the ones that discovered outside the world of the universe is astronauts. So I would really like it if they really had more descriptions of astronauts because they really had inside scientists that work in a lab now that's great, but they sit in a chair. And the people that go up into space, they really make a sacrifice for their life because we really don't know what can happen out there.*

Discussion

The independent evaluation team from Knight Williams Inc. conducted a summative evaluation of the SOTU project in two phases. Phase 1 addressed the impact on 5th to 8th graders of viewing online seven minutes of small screen videos, focused either on science content or science characters, prior to viewing on the next day the 40-minute SOTU giant screen film. The evaluation assessed the impact of the pre-film types on the film experience, the appeal of the film itself, and the impact of both media on perceived student learning and interest regarding science and scientists, with additional analyses by gender and by younger and older grade levels.

Through conversation groups with middle school girls, Phase 2 further explored girls' experience with the science characters in the pre-film videos and film, focusing on the impact of the science characters on the girls' thoughts about scientists and their opinions of the effectiveness of the science characters as role models in encouraging their interest in science.

In total, 190 middle school students participated in Phase 1, 20 of whom were girls who also participated in Phase 2. Of the participating students, 51% viewed the pre-film science content videos and 49% viewed the pre-film science character videos. The two independent groups did not differ significantly with respect to gender, age, and minority/non-minority distributions. However, due to an uneven distribution of which grades viewed which pre-film videos, 5th, 6th, and 7th graders were combined into a younger grade level group and compared with the older 8th grade level in analyses.

This discussion first focuses on statistically significant findings from Phase 1 related to the evaluation question: *Do post-film responses regarding learning and interest differ for students who see pre-film science content videos vs. those who see pre-film science character videos, and does gender or grade level play a role?* The section on the role of gender in the experience of pre-film videos and film also reflects on findings from the Phase 2 girl conversation groups. The report discussion then concludes with recommendations that the project team may want to address while the film is still showing in theaters.

Impact of pre-film videos on students' film experience

More than two-thirds of students thought the videos affected their film experience. Compared with those who watched character pre-film videos, students who watched content pre-film videos were significantly more likely to say the videos increased their understanding of the film's topic and to report that what they liked about the film was LHC research or LHC technology. Those who watched content videos were significantly more likely to report that what stood out for them in their videos was the LHC technology (the Collider, its size and location, and how it works) or LHC research (about atoms, protons, and collisions); whereas those who watched character videos were significantly more likely to note that the scientists stood out for them in the pre-film experience. These results point to the positive impact of these videos on students' experience of the film's science and scientist content.

Role of pre-film videos on learning about and interest in science and scientists

Video type viewed showed significant differences in multiple areas related to students' self-reported learning from the videos and film. Students who reported having learned about the Collider from the videos and film were significantly more likely to have watched the content videos than the character videos. Those who saw the content videos also agreed significantly more strongly with the statement "I learned more about how the Collider works to produce particle collisions." In contrast, those who watched the character videos were significantly more likely to report having learned that anyone can be a scientist, and they agreed significantly more strongly with the statement "I am more aware that young people from every background can become scientists." Thus, learning was differentially impacted by type of pre-video viewed; however, video type did not differentially impact students' interest in either science or scientists.

Role of grade level in the experience of pre-film videos and film

Grade level had a significant impact on the appeal of the film overall, and on various aspects of the film. Compared with the older 8th grade level, the younger combined grade level of 5th, 6th, and 7th graders liked the film significantly more and reported the scientists as appealing significantly more frequently. The younger grade level also rated the film's presentation of science content and presentation of scientists as significantly more interesting.

Grade level also showed an impact on self-reported learning from the pre-film videos and film. Although the younger grade level rated the level of science as significantly more advanced than the 8th graders, the younger grade level reported feeling a significantly higher increase in science knowledge and knowledge about scientists compared with the 8th grade level.

Interest in science and scientists was also greatly influenced by grade level. Compared with the 8th grade level, the younger grade level reported feeling a significantly higher increase in both interest in science and interest in scientists. The younger grade level described significantly more often the focus on atoms, protons, or particle collisions as affecting their learning about science and significantly more often the focus on scientists of the past or their discoveries as affecting their interest in scientists. Additionally, they agreed more strongly than the 8th graders that they were more interested in how scientists from the past have contributed to the science of today, more interested in scientists and the kind of work they do, and more interested in searching out more information about scientists featured in the videos and film.

Even though the advanced physics content of the film is not typically addressed in middle school science curriculum, these findings indicate that the project team will likely want to continue outreach to younger middle school students and school groups, and as part of this outreach suggest the use of pre-film resources to help prepare them for the science content.

Role of gender in the experience of pre-film videos and film

Compared with the boys, the girls showed a few significant differences in the areas assessed in the evaluation. When asked what they liked about the film, girls were significantly more likely than boys to report liking an aspect of filmmaking but significantly less likely to report liking the focus on LHC technology or LHC research. Girls also disagreed more strongly than boys with the statement "I learned more about how the Collider works to produce particle collisions." When

asked what they learned from the videos and film about science and scientists, girls were significantly more likely than boys to report that they had learned about scientists or their discoveries and significantly less likely to say that they had learned about the Collider. Regarding the impact of the videos and film on their interest in scientists, girls were significantly more interested than boys in the focus on scientists of the past or their discoveries. It appears that girls responded more positively to the human character qualities and aesthetics of the videos and film than to the science content.

These observations about girls' distinct interests carried through in more detail in the conversation groups. Whether talking about identified role models in their lives (often family members) or scientists in the videos and film, human character qualities most often focused on being hardworking and on being an influencer/inspirer/difference maker. Comments about science content (for example pertaining to atoms or how the Collider worked) were few and usually included appreciation of the visualizations and aesthetics of the images.

Most salient in the conversation groups were girls' interest in the backstory or background of many of the science characters, particularly in the conversations about the effectiveness or ineffectiveness of the role models and in the selection of specific scientist role models from the SOTU media. One of Dr. Calderón de la Barca Sanchez's UC Davis graduate students, Dr. Santona Tuli, was most often identified as an effective role model by the girls, followed by the historical scientists. Dr. Tuli's background was most developed, and frequently referenced, as it was the focus of one section of the pre-film videos; although a criticism of the SOTU media was that even more background was desired, both in general and when describing Dr Tuli in particular.

Finally, in describing the influences of the videos and film, it should be noted that the diversity of the scientists, and notably the inclusion of Dr. Tuli and Dr. Calderón de la Barca Sánchez, expanded some girls' understanding of the humanness and diversity of scientists as well as the collaborative nature of science.

Recommendations

The findings summarized above, along with an overarching consideration of the Phase 1 and Phase 2 findings detailed in this report, point to three suggestions the project team might consider while the film is still showing in theaters.

- First, consider expanding or highlighting the number and depth of information about female scientists in the supplemental materials. Given the project goal of appealing to middle school girls, the team might do more to showcase the work of scientists past and present in the SOTU resources. For example – although the biographies of historical figures from the film are currently linked at the bottom of the About the Film page – making them more prominent on the website, including more images or editing them to be less text-heavy, and/or creating video clips about these scientists' work and how such work connects to current research at the LHC might help further increase girls' interest in science and scientists. To appeal to girls' interest in the human aspect of science, and to make the science content more appealing, the project team might also create videos of female scientists explaining the LHC research and technology, as well as focusing on their life stories or their path to science.

- Second, develop strategies to address misunderstandings about both science content and the process of science. Although most students were able to identify something they thought they learned about science from the videos and film, the evaluation team noted three areas of confusion throughout their survey responses: confusion about the heat generated by the collisions ("*I didn't know there is a type of atom hotter than the sun"*), confusion about the force holding together quarks ("*It was interesting how they talked about the strongest force in the universe and that makes me wonder what exactly is the strongest force"*), and confusion about the Collider's "time machine" capabilities ("*I love that they showed us how they built the time machine. I always believed that we would be able to go back in time and they showed us that we can actually go back in time even if it was a couple of seconds")*.

  To address these areas of confusion, the project team might add a glossary and/or a Frequently Asked Questions section (FAQ) to the SOTU website. The glossary could use videos or graphics to explain terms such as quark, ion, quark-gluon plasma, lead ion collisions, collision-generated temperatures, and the metaphor of the LHC time machine. An FAQ section might be a bit less didactic and would provide an opportunity to reframe confusions (*What is the strongest force in the universe? Can the Collider transport us back in time?*) while also addressing some of the negative assumptions/ideas some students might have about science (*How likely is that that the collider can explode?*).

  Although the SOTU Interactive Experience, linked on the SOTU home page and hosted on the Perimeter Institute's website, addresses some confusions related to heat, force, and time travel, a website visitor might not think to explore the Interactive Experience looking for answers to any questions they might have. Creating a glossary and/or FAQ section would give online visitors more obvious places on the SOTU website to go for more information, should they have specific questions about content from the film.

- Third and finally, consider strategies for promoting and providing the pre-film videos to teachers. Given that the evaluation showed positive results from the use of science content and scientist character pre-film videos with middle school students, the project team may want to package some of the pre-film videos together into one or more playlists that touch upon both topics. For example, packaging together the Great Machines in Science: The Large Hadron Collider video and the film's scientist-focused trailer would have a total run time of 2:44 minutes, which could be assigned for at-home viewing in instances where classroom time is limited and students have at-home internet access. Alternately, for educators who have the time to go more in-depth in the classroom, packaging together the Inside the World's Largest Particle Accelerator video and Dr. Santona Tuli's character profile video would have a longer run time of 9:19 minutes. Similarly, packaging the Inside the World's Largest Particle Accelerator video with Manuel Calderón de la Barca Sánchez's team spotlight video would have a run time of 8:25 minutes.

References

Flagg, B., Knight-Williams, V., & Sullivan-Hall, P. (2019). *Secrets of the Universe* formative evaluation with middle-school youth of fine-cut version of giant screen film.

Knight-Williams, V., & McCreedy, D. (2019). *Secrets of the Universe* giant screen film fine-cut review: Compilation of youth advisor and STEM gender media expert responses.

Appendix 1. *Secrets of the Universe* survey for middle school students

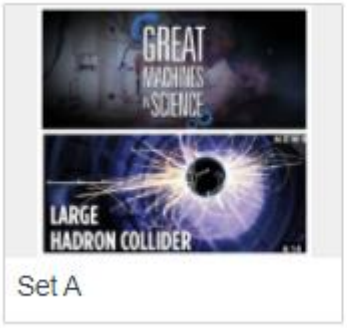
This survey asks for your feedback on the *Secrets of the Universe* videos you watched at home yesterday and film you watched at MOSAC today. Completing this survey is voluntary. Your responses are private and will be combined with those from other students. There are no right or wrong answers; we are just looking for your honest feedback. Your responses will help inform future videos and films, so we appreciate your taking the time to answer these questions!

1. First, please write your first and last name here just so that we can confirm we received surveys from all of the students who participated. Your name will not be connected with your responses in any way. Remember your responses are private and will be combined with those from other students.

As a reminder, your experience with *Secrets of the Universe* included watching a short set of videos at home yesterday and then seeing the film at the Museum of Science and Curiosity (MOSAC) today.

The first few questions ask about the videos you watched at home and how they affected your experience of the film at MOSAC.

2. Yesterday you watched one set of videos at home while other students watched a different set of videos that day. Which set did you watch? Please circle one box only. If you can't remember which set you watched, you can ask your session leader.



3. Try to recall what you saw in these videos at home then answer the question below.

What about the videos stood out for you?

4. Check one answer to complete the following sentence about how watching the videos affected your experience of the film at MOSAC:

   Watching the videos....

   - ❍ positively affected my experience of the film at MOSAC
   - ❍ did not affect my experience of the film at MOSAC
   - ❍ negatively affected my experience of the film at MOSAC
   - ❍ I did not see the videos before seeing the film at MOSAC

5. As best you can, please explain how the videos [*positively/didn't/negatively*] affected your experience of the film at MOSAC. Please be as specific as possible in your explanation.

Now think just about the film you viewed at MOSAC...

6. What 2 things did you like most about the film? Also, please explain why you liked each thing.

7. What 2 things did you not like about the film? Also, please explain why you disliked each thing.

How do you feel about the following aspects of the film you viewed at MOSAC? Please click on one number on the scale from 1 to 5 for each of the following pairs of descriptions below, with 3 being "neutral."

8. How did you feel about the film overall?

						Liked
Disliked	1	2	3	4	5	

9. How did you feel about the film's presentation of scientists?

Boring	1	2	3	4	5	Interesting

10. How did you feel about the film's presentation of science content?

Boring	1	2	3	4	5	Interesting

How do you feel about the following additional aspects of the film you viewed at MOSAC?

11. How did you feel about the clarity of the film's science presentation?

Confusing	1	2	3	4	5	Clear

12. How did you feel about the level of science in the film?

Science too basic	1	2	3	4	5	Science too advanced

For the remaining questions, please think about your <u>overall</u> media experience with *Secrets of the Universe* this weekend, including the videos you watched at home and the film you saw at MOSAC.

13. How much did your experience with the *Secrets of the Universe* videos and film affect your <u>knowledge of science</u>?

- ❍ Increased my knowledge a lot
- ❍ increased my knowledge moderately
- ❍ Increased my knowledge somewhat
- ❍ Increased my knowledge a little
- ❍ Did not affect my knowledge

14. Describe 2 things you learned about science that you did not know before your experience with the *Secrets of the Universe* videos and film?

15. How much do you disagree or agree with each of the statements below about your experience with *Secrets of the Universe* videos and film*?*

As a result of my experience with *Secrets of the Universe*, I learned more about….	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
how the Collider was engineered and constructed.	1	2	3	4	5
how the Collider works to produce' particle collisions.	1	2	3	4	5
how difficult it is to make the Collider work perfectly.	1	2	3	4	5
how the Collider can be used to explore fundamental questions in science.	1	2	3	4	5

16. How much did your experience with the *Secrets of the Universe* videos and film affect your knowledge of scientists?

- ❍ Increased my knowledge a lot
- ❍ increased my knowledge moderately
- ❍ Increased my knowledge somewhat
- ❍ Increased my knowledge a little
- ❍ Did not affect my knowledge

17. Describe 2 things you learned about scientists that you did not know before your experience with the *Secrets of the Universe* videos and film?

18. How much do you <u>disagree or agree</u> with each of the statements below about your experience with *Secrets of the Universe* videos and film*?*					
As a result of my experience with *Secrets of the Universe…*	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I learned that scientists from the past can play an important role in the science that is practiced today.	1	2	3	4	5
I am more aware that young people from every background can become scientists.	1	2	3	4	5
I learned that scientists from many countries work together in teams.	1	2	3	4	5
I better understand the struggles scientists go through with their research.	1	2	3	4	5
I am more aware of the passion and excitement that scientists have for their work.	1	2	3	4	5

19. How much did your experience with the *Secrets of the Universe* videos and film affect your <u>interest in science</u>?

- ❍ Increased my interest a lot
- ❍ increased my interest moderately
- ❍ Increased my interest somewhat
- ❍ Increased my interest a little
- ❍ Did not affect my interest

20. Describe 2 things about the *Secrets of the Universe* videos and/or film that affected your <u>interest in science</u>.

21. How much do you disagree or agree with each of the statements below about your experience with *Secrets of the Universe* videos and film:

As a result of my experience with *Secrets of the Universe*, I am more interested in…	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
how the Collider was built.	1	2	3	4	5
the different kinds of experiments and research the Collider is capable of.	1	2	3	4	5
how the Collider can be used to do research about the universe.	1	2	3	4	5
searching out information about how the collisions occur in the Collider.	1	2	3	4	5
learning about the tiniest particles in nature.	1	2	3	4	5

22. How much did your experience with the *Secrets of the Universe* videos and film affect your interest in scientists?

- ❍ Increased my interest a lot
- ❍ increased my interest moderately
- ❍ Increased my interest somewhat
- ❍ Increased my interest a little
- ❍ Did not affect my interest

23. Describe 2 things about the *Secrets of the Universe* videos and/or film that affected your interest in scientists.

24. How much do you <u>disagree or agree</u> with each of the statements below about your experience with *Secrets of the Universe* videos and film?					
As a result of my experience with *Secrets of the Universe*, I am more interested in…	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
scientists and the kind of work they do.	1	2	3	4	5
how scientists from the past have contributed to the science of today.	1	2	3	4	5
exploring pathways I could take to become a scientist.	1	2	3	4	5
learning about jobs or careers in science.	1	2	3	4	5
searching out more information about the scientists featured in the videos and film.	1	2	3	4	5

The final few questions are to help us ensure the feedback session is inclusive and is gathering feedback from students of diverse backgrounds across Sacramento. Thanks for helping us to learn a little more about you.

25. How old are you? _____

26. What is your gender? _____

27. Please check one or more boxes to describe your major racial/ethnic background:

- ❑ African American/Black
- ❑ Asian (e.g., Asian Indian, Chinese, Japanese, other)
- ❑ Hispanic, Latino, or Spanish origin
- ❑ Indigenous or Alaskan Native
- ❑ Native Hawaiian or Pacific Islander
- ❑ White
- ❑ Other: Please describe:_____

28. What is your grade in school?

❍ 5th ❍ 6th ❍ 7th ❍ 8th ❍ 9th

29. What is the name of the school you attend?

Thank you for your feedback!

Appendix 2. *Secrets of the Universe* Phase 2 guiding questions for conversation groups

1. Do you feel that the videos or film changed how you think of scientists?
    - 1a. *If yes*: How did watching the videos or film change how you think of scientists?
    - 1b. *If no*: Why do you think that the videos or film did not change how you think of scientists?

2. Could you see yourself in any of the scientist roles pictured onscreen in the videos or film? Why or why not?

3. I'd like to continue our discussion today by talking about what the term 'role model' means to you. Jot down two or three words that come to mind when you hear the term role model.

   Can you think of anyone in your life or in the media who is a role model for you?
   If yes, please explain how they are a role model for you.

4. Let us now consider role models in the area of science. What characteristics would make a role model most effective in encouraging your interest in science?

5. Here [*show collage of pics*] are some of the science people that were shown in the videos you watched at school and in the film at MOSAC, including the scientists doing work at the Collider, the young scientists on Manuel's team, and the historical scientists from the past. Think back to the characteristics of an effective science role model that we just talked about.
    - In what ways were any of the scientists you saw effective role models in encouraging your interest in science?
    - In what ways were any of these scientists not effective role models?
    - (if not discussed) What about the women scientists in particular – how were they effective or not effective role models for you?

6. Think about how the women scientists were presented in the videos and films, the settings they were in, what they were doing, and what you learned about them. Is there anything you would change or add to their portrayal to make them better role models for you and other girls your age? If yes, what would you change or add?