Influence of Immersion on Visitor Learning:

Maya Skies Research Report

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Prepared for:
Chabot Space and Science Center

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Understanding, fostering, and promoting lifelong learning

Executive Summary

In 2007, Chabot Space & Science Center, along with partners LodeStar Astronomy Center and the Institute for Learning Innovation, received a National Science Foundation grant to develop, create, distribute, and conduct learning research on a full-dome planetarium show which was eventually titled *Tales of the Maya Skies.* The show was intended to be physically immersive and transport the viewer to ancient Maya civilizations and also to push the boundaries of the narrative approach used for most planetarium shows by including a "cultural wrapper" of the Maya people and their archaeo-astronomy.

The Institute for Learning Innovation was tasked with conducting a research study to determine the strategic impact of *Tales of the Maya Skies*. The study was designed to address three questions:

What is the impact of physical immersion on learning?
What is the influence of the "cultural wrapper" on learning?
What parts of the physically immersive show create a strong response?

The first question was addressed by comparing short-and longer-term learning between three contexts of seeing *Tales of the Maya Skies*: immersive, semi-immersive, and small screen. To address the second question, a study was conducted to compare the short-term response of two populations of Chabot visitors with varying personal connection to the Maya. This included collecting data from visitors attending Spanish language screenings of the film, as well as using cultural identifiers across participants in the study. The third question examined the relationship between specific elements of the *Tales of the Maya Skies* show and real-time data on physiological and opinion response.

All three sub-questions of the physical immersion study revealed there are positive differences based on the size of the screen in terms of viewer perception of immersion, perception of the overall show and visuals, and viewer learning, with the full-dome receiving the most positive results across the board. An interesting finding was that scores from television viewing followed the full-dome in terms of positive outcomes and visitor perceptions of the show overall, with the large screen trailing these formats.

The study to understand the influence of the cultural wrapper on learning and opinions was guided by seventeen sub-questions, and the findings were mixed. Overall, those who viewed the Spanish language version of the show had the greatest differences, having more positive perceptions of the show, its visuals, preference for the storylines, and learning outcomes. Other factors that showed a relationship to increased positive perceptions of the show, its visuals, and what they liked included incoming viewers' self-reported interest, knowledge, and connection to Mayan culture; knowledge and connection to astronomy; and interest in Maya culture. The findings, however, were inconsistent related to visitor learning between groups. Interest in astronomy revealed differences between groups on the overall show, visuals of the show, what they liked about the show, and on visitor learning, while prior knowledge of Mayan culture did not. Age was related to very few differences between groups, and there were no differences based on sex.

For the third study, there were three sub-questions relating to the connection between the show's scenes and physiologic and opinion response and to degree of change in response between sequences. Visitors' opinions appeared to relate strongly to content and presentation, whereas physical response seemed more related to the immersive experiences. Prior astronomy knowledge does appear to influence opinion ratings with those who have moderate levels of entry knowledge having the most positive and consistent opinions of the show overall.

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Introduction

Project Background

In 2007, Chabot Space & Science Center received a National Science Foundation grant (#0610253), in partnership with LodeStar Astronomy Center and the Institute for Learning Innovation, to develop, create, distribute, and conduct learning research on a full-dome planetarium show, which was eventually titled *Tales of the Maya Skies*. The show was intended to be physically immersive, using the full-dome environment and cutting edge technology for creating visual effects that would transport the viewer to ancient Maya civilizations. The show was also intended to push the boundaries of the narrative approach used for most planetarium shows, by producing a show that told astronomical stories and concepts through the lens and "cultural wrapper" of the Maya people and their archaeo-astronomy. The story was told from the point-of-view of the Maya, using their cultural perspective as the starting point to explain astronomical phenomena and the impressive scientific achievements reached by the ancient Maya people.

As partners on this project, the Institute for Learning Innovation (ILI) was tasked with conducting a research study to determine the strategic impact of *Tales of the Maya Skies*. This research study was designed to address how the immersive experience and personal relevance of this unique planetarium approach might impact learning over time. The study used the full-dome facilities at Chabot Space & Science Center (Chabot) and alternative screen versions at COSI, a science center in Columbus, OH, to compare and contrast immersive (full-dome) and non-immersive (flat screen and small screen) environments, and the impact of perceived personal relevance on learning and enjoyment. The purpose of this study was to provide results to establish a baseline of evidence for the degree to which full-dome technology, coupled with the use of a cultural narrative, might benefit audiences in unique ways.

Review of Literature

There is an assumption that the experience of viewing an educational film in a dome or giant screen theater leads to more powerful learning outcomes. However, a recent review of the literature reveals that this assumption has yet to be adequately tested (Fraser, Yocco, & Sickler, 2010). The current state of the literature suggests that one line of inquiry has involved identifying the components that make these experiences unique (e.g., immersion and telepresence) and perhaps enhance learning, while a separate track has focused on evaluating the outcomes of specific National Science Foundation-funded giant screen films. To provide background for the research conducted here, we will briefly review the components that comprise the unique experience of viewing a giant screen/dome film, and some of the findings from evaluation studies that have been conducted on these films to date, as identified in this recent review of the literature (Fraser et al., 2010).

Dome and giant screen theaters in science centers are immersive environments (Lantz, 2007). Immersive environments allow for those participating in programming to lose the sense that they are merely watching a film on a screen, transporting these viewers' minds to the virtual reality created by the film. Immersion is thought to be a key component of enhancing the learning experience of viewing a giant screen film (Fiore, Harrison, Hughes & Rutstrom, 2009). In fact, some researchers have suggested and found that immersive environments can contribute to and enhance the learning of scientific concepts, including Earth and space science concepts (Angelov, Smieja, & Styczynski, 2007; Barab, Barnett & Keating, 2000; Barnea & Dori, 1999; Keating, Barnett, Barab & Hay., 2002; Murphy, 2004;

Yeung, 2004). Further, researchers suggest immersive environments may increase individuals' interest and motivation for learning more about the scientific concepts encountered in immersive environments (Korakakis, Pavlatou, Palyvos & Spyrellis., 2009).

Telepresence or "the sensation of being with and connecting to people, objects, and events" (Lombard, 2008) is another factor identified in the literature as contributing to the potential for enhanced learning from dome and giant screen films. As with immersion, the sensation of telepresence relies heavily on the size of the screen a film is viewed on (Lombard, Ditton, Grabe, & Reich, 1997; Lombard, Reich, Grabe, Bracken, & Ditton 2000). Although there are over 1,800 publications focusing on telepresence across a variety of fields, there is a notable lack of research on this phenomenon in dome or giant screen theaters and on the differences in learning outcomes that may be attributed to a sense of presence. Lombard and Ditton (2007) speculate that a sense of telepresence is caused by films in immersive environments, and that this may be a critical tool in shaping positive attitudes towards science and increased scientific knowledge.

Storytelling is a third critical factor identified as contributing to the learning outcomes of dome/giant screen films (Apley, 2008). Atkins (2008) notes that quality storytelling is as critical as the audio-visual experience in promoting learning outcomes in dome/giant screen films. Realistic dialogue and acting contribute to an audience making a connection with a film topic, as well as promote the occurrence of telepresence. Apley (2008), in a review of her evaluations of giant screen films, notes several parallels between audience outcomes and elements of storytelling taking place during specific segments of film.

Finally, Flagg (2005) conducted a review of the findings from 10 evaluations on giant screen films that received National Science Foundation funding. Flagg found that learning outcomes for these evaluations focused on changes in viewers' "verbal knowledge," with each film demonstrating significant increases in viewers' verbal knowledge. Findings from these evaluations suggest that for some or all of the films investigated viewers experience an increase in content knowledge, an increase in interest in the film topic, and credit the film with influencing their thoughts or actions in the week following viewing the film. Apley (2008) and Knight-Williams echo Flagg's (2005) findings in their evaluations of separate National Science Foundation funded films. These findings include viewers experiencing an increase in content knowledge and retaining key messages in the weeks following viewing a film.

This search and review of the literature revealed that a gap exists in demonstrating that dome/giant screen experiences enhance the learning, as compared to other, less-immersive environments. Evidence was not found to indicate that differences in learning due to levels of immersion or telepresence have been explored in prior studies. This highlights the need for studies such as those developed and reported as part of the Maya Skies project.

Research Questions and Study Design

Three dominant questions drove the research study. These were:

What is the impact of physical immersion on learning?
What is the influence of the "cultural wrapper" on learning?
What parts of the physically immersive show create a strong response?

Three distinct study designs were developed to address each of these research questions. To address the first question, the study examined the influence on learning of the physically immersive experience of the full-dome show (i.e., feeling like you're there) by comparing short- and long-term learning between three contexts of seeing *Tales of the Maya Skies*: immersive, semi-immersive, and small screen.

To address the second question, the study examined the influence on learning of the "cultural wrapper" of *Tales of the Maya Skies* (i.e., presenting science information via a cultural narrative) by comparing the short-term response of two populations of Chabot visitors with varying personal connection to the Maya. This included collecting data from visitors attending Spanish language screenings of the film, as well as using cultural identifiers across participants in the study.

To address the third question, the study examined the relationship between specific elements of the *Tales of the Maya Skies* show and real-time data on physiological and opinion response, as well as post-show learning. All research was conducted through collaboration with the research partner, OSU Extension under Ohio State University IRB 2010E0406 (Questions 1 and 2) and 2010B0107 (Question 3).

Methods

Research Question 1: What is the impact of physical immersion on learning?

This question led to a comparison of learning by visitors seeing *Tales of the Maya* Skies in three different conditions of physical immersion: full-dome, movie screen, television screen (representing immersive, semi-immersive, and non-immersive, respectively). Variables also measured for comparison were sense of immersion, satisfaction, and interest.

Data for this study were collected at screenings of *Tales of the Maya Skies* in three different conditions:

- Chabot – full-dome planetarium show
- COSI Galaxy Theater – standard large screen
- COSI – 42" television set

It was not possible to conduct the semi-immersive and non-immersive conditions at Chabot, as it would have caused a detriment to the visitor experience. Since researchers were interested in those visitors electing to see *Tales of the Maya Skies*, substituting the alternate, less immersive conditions for those visitors would likely have negatively impacted those visitors who had sought to see the show in the full-dome. Therefore, the alternate conditions were studied at COSI, where *Tales of the Maya Skies* was not on the museum's screening schedule and represented an additional viewing opportunity for visitors.

For data collected at Chabot, participants were recruited from adult visitors who had purchased tickets to see *Tales of the Maya Skies*. Data were collected from 155 visitors on Fridays, Saturdays, and Sundays between April 9 and May 16, 2010. For data collected at COSI, participants were recruited at the COSI box office following admission ticket purchase or approached during their visit by researchers and asked to participate in viewing the show and completing the questionnaires. Data were collected from 77 visitors (38 to the theater screen, 39 to the TV screen) on June 12, 13, and 17, 2010.

In both settings, data collectors recruited participants from visitors who stated they were age 18 and above. They were recruited with a brief verbal description of the study, what participation would entail, and were informed they were under no obligation to complete the study and that they did not have to

answer any questions with which they were not comfortable. Visitors who agreed to participate completed a pre-show questionnaire containing items of self-reported interest and knowledge in Maya culture, knowledge of Maya culture, knowledge of astronomy, and basic demographic characteristics, then viewed *Tales of the Maya Skies*. After the show, they completed an immediate-post questionnaire including semantic differential scales describing the show and its visuals, items measuring the degree to which the show communicated specific concepts and told specific stories, and participants' interest in specific stories told by the show. Respondents were requested to provide contact information for a follow-up web questionnaire, which was administered via email roughly six weeks after the screening. Upon handing in the post measure, participants were given a small token of appreciation, a *Tales of the Maya Skies* refrigerator magnet, for completing both questionnaires. Participants were not aware that they would receive the token of appreciation prior to returning their questionnaires.

Participants who viewed the show in each setting were also asked to participate in a delayed-post questionnaire. Participants were asked to provide their email address so that a link to an online questionnaire could be sent to them. Participants who provided a valid email address were contacted six to eight weeks after viewing the show, with a request to follow a web link to complete the questionnaire. This email informed participants they were under no obligation to complete the questionnaire, that no identifying information was being collected from them, and that the time commitment to complete the questionnaire would be approximately 10 minutes. A reminder email was sent to non-responding participants approximately one week following the initial email asking them to take the questionnaire.

For detail on items asked for this research question, see questionnaires in Appendix A.

Research Question 2: What is the influence of the "cultural wrapper" on learning?

This study used a comparison of visitors to the Spanish language version of *Tales of the Maya Skies* with visitors to the English language version of the show. Data for this study were collected at regularly scheduled screenings of *Tales of the Maya Skies* at Chabot:

- *Tales of the Maya Skies*, presented with English narration
- *Tales of the Maya Skies*, presented with Spanish narration

The population for study within this research question was expanded to include those visitors attending the Spanish narration version of *Tales of the Maya Skies* because data from front-end evaluation (Stein, 2007) indicated that many members of the local Hispanic community had family origins and ties to communities of Mexico, Guatemala, and Honduras, and felt personal connections with the Maya people. In an effort to gather data from visitors from these communities, the Spanish language screenings were included in data collection. Nevertheless, researchers did not presume that show language was the sole determinant of cultural connection, and self-report measures of connection were included within the pre-show questionnaire. It was these measures that were used to classify visitors.

For all data collected at Chabot, participants were recruited from visitors who verbally stated they were 18 and above and had purchased tickets to see either screening of *Tales of the Maya Skies*. Data were collected between April 9 and May 30, 2010. Responses were obtained from 155 visitors to the English narrated version of the show (these were the same participants as in research question 1). Data were collected from 23 visitors to the Spanish narrated version of the show. The sample size for visitors of the Spanish-narrated show was substantially lower than anticipated due to low attendance at these

shows. Data collectors successfully obtained participation from nearly all visitors who viewed the Spanish-narrated shows during the period of research.

Data collectors recruited participants with a brief description of the study and what participation would entail; potential participants were informed that they were under no obligation to complete the study and that they did not have to answer any questions they were not comfortable with. Visitors who agreed to participate completed a pre-show questionnaire containing items of self-reported interest and knowledge in Maya culture, knowledge of Maya culture, knowledge of astronomy, and basic demographic questions. After viewing *Tales of the Maya Skies*, participants completed an immediate-post questionnaire, which included semantic differential scales about the show and its visuals, items measuring how much the show communicated specific concepts, how well the show told specific stories, and how much the participants like the specific stories told by the show. The immediate-post questionnaire also contained open-ended items on what participants learned from the show. The questionnaires were offered in either English or Spanish for participants viewing the Spanish-language show.

Respondents were requested to provide contact information for a follow-up web questionnaire, which was administered via email roughly six weeks after the screening. Upon handing in the post measure, participants were given a small token of appreciation, a *Tales of the Maya Skies* refrigerator magnet, for completing both questionnaires. Participants were not aware that they would receive the token of appreciation prior to returning their questionnaires.

For detail on questions asked for this research question, see questionnaires in Appendix B.

Research Question 3: What parts of the physically immersive show create a strong response?

This component of the study explored how the immersive experience and cultural narrative of *Tales of the Maya Skies* impact visitors' cognitive, affective, and physiological response. The study utilized the full-dome facilities at Chabot to study viewers' physiologic response (via heart rate and skin conductance) to specific elements of the immersive show, real-time opinions of the immersive show, and pre-/post- measures of learning and satisfaction. Triangulation of real-time physiologic and opinion data points with the timeline of the actual show provides insight into the aspects of the immersive show and cultural narrative that created the strongest response in visitors.

Several pieces of physiologic data were collected in this study: heart rate, respiratory sinus arrhythmia (RSA) (both measured through EKG), and galvanic skin response (GSR; also known as electrodermal response or skin conductance response). These three physiological data were used as measures of viewer arousal during the full-dome show. Portable, non-invasive equipment (developed by MindWare, Inc.) was used to collect this data. For this study, a total of five disposable, adhesive electrodes were affixed to the visitor's skin – two to the palm of the non-dominant hand to measure GSR; and two to the forearm of left hand and one to the forearm of the right hand to measure EKG. Electrode wires were then attached to a PDA (HP Pocket PC) that rested on visitor's lap during the show, transmitting the data wirelessly to a laptop computer.

Real-time opinion data was collected through a small control dial (also connected to the laptop computer system), which visitors could turn clockwise or counter-clockwise throughout the presentation to indicate their level of enjoyment of the show at any given moment.

Equipment capabilities allowed researchers to collect this data from a maximum of four visitors per screening of *Tales of the Maya Skies*. In total, 35 visitors participated in this study between July 16 and 18, 2010.

Recruitment of Participants and Data Collection Procedure

Adult visitors (age 18 and older) were recruited to participate in this study in advance of the study. This pre-recruitment (as opposed to the on-site recruitment of the other studies) was used to provide participants with sufficient time to understand the study components and provide informed consent. All recruitment was conducted by Chabot, via email announcements to members and other interested museum-goers who had previously signed up for email information. Potential participants who responded to the recruitment were provided with information about the study, requirements of participation, risks, benefits, and incentive information (two free admissions for non-members or an equivalently valued gift certificate for Chabot members). Those interested in participation were scheduled to attend a specific screening of the show.

In total, full participation in the study took approximately 75-80 minutes: 30 minutes prior to the show, 35 minutes of the show screening, and 10 minutes after the show. In the 30-minute period prior to the scheduled show, participants met researchers in the lobby just outside of the theater, where they were provided with a copy of the consent form and had the opportunity to re-read the document and ask any questions. If participants agreed, they signed the form and were given a numbered ID bracelet, which was used to link each piece of data collected (surveys and physiological data) without their identifying information. Skin was cleaned with alcohol swabs, and adhesive electrodes were attached to the forearms and hands; allowing the gel of electrodes to be in contact with the skin for as long as possible prior to the screening proved to increase effectiveness of readings. Participants then completed a pre-show questionnaire.

After completing the questionnaire, participants were taken into the theater and seated in a pre-identified row of seats for the maximum degree of immersion of their field of vision. Wires were attached between the electrodes and PDAs, and were affixed to participants' skin with medical tape (to minimize extraneous movement and noise in the physiological data). Researchers tested the signals of each participant's EKG and GSR monitoring equipment, making adjustments if necessary and possible, prior to the scheduled start of the show. Researchers then distributed the opinion rating-dials, provided the condition of instruction for using the dials during the show. A two-minute period of baseline data was recorded, while the participants sat quietly prior to the show and while other visitors entered the theater. In some cases, the entry of other visitors distracted participants during the baseline reading, and in two instances, baseline readings were reduced to one-minute, given constraints of scheduled screening times.

Researchers started data recording with the opening sound of the show, and observed participants during the show, noting (when possible) any events that took place outside of the film that may have affected response (i.e., a child crying in the audience; a participant sneezing). At the completion of the show, wires and electrodes were removed, and participants were taken to a nearby classroom to complete the post-show questionnaire, which took approximately 10 minutes.

For detail on questions asked for this research question, see questionnaires in Appendix C.

Analysis

Data were entered into SPSS spreadsheets and analyzed using central tendencies, reliabilities, measures of significance (Chi Square, ANOVA), point-biseral correlations, and MANOVA. Qualitative data were analyzed for trends and themes. Specific data processes are shared in the findings sections for each of the studies.

Analysis of physiologic and real-time opinion data was conducted using analysis software from MindWare Technologies (HRV ver. 3.0.4 and EDA ver. 3.0.4). Physiologic data (EKG and GSR) were first reviewed and cleaned, examining each individual's data for evidence of noise or extraneous events, so that these were not included in analysis. For accuracy in mean heart rate measures, data were analyzed in 60-second segments (with 31 segments comprising the entire show; closing credits were not included in analysis). Consequently, GSR and opinion data were also analyzed in 60-second segments. The analysis software provided data outputs for each segment of analysis. Relevant data from outputs (mean heart rate, RSA, skin conductance level, number of skin conductance events, and mean opinion rating in each segment) were compiled and transferred to SPSS analysis and compilation with self-report measures.

Results: Study 1 – Focus on Screen Size

Questions

The overarching research question for this component of the study was "What is the impact of physical immersion on learning?" To answer this question, five specific questions related to screen size as the independent variable were addressed:

1) Are there differences, based on the size of the screen the show is viewed on, in viewer perception of immersion?
2) Are there differences, based on the size of the screen the show is viewed on, in viewer perception of the overall show and visuals of the show?
3) Are there differences, based on the size of the screen the show is viewed on, in viewer learning?
4) What changes in learning from the show do viewers express over time?
5) Are there differences over time, based on screen size, in viewers' interests and behaviors related to the topics covered in the show?

Measurements

Independent Variable: Screen Size

There were three screen sizes compared in this study: full-dome (Chabot), theater-style flat screen (COSI), and a 42" flat-screen television (COSI).

Dependent Variables: Sense of immersion, perceptions of the show, and viewer learning

Sense of immersion

Participants were asked to rate on a seven-point scale the degree to which they agreed with each of the following items while viewing the show.

- I was surrounded by images and sound.
- I was in the middle of the experience
- I was watching a program.
- I was in a program.
- I was transported to a different place.
- My body was here buy my senses were taken somewhere different.
- I was visiting a different place and time.

Cronbach's alpha for the seven items in the immersion scale was .860.

Perception of overall show

After viewing the show participants were given a scale containing six semantic differential pairings of words. These pairings were designed to measure the positive-negative perceptions participants had of the show in general. Positive perceptions of the show were: good, entertaining, informative, comprehensible, objective, and stimulating. Negative perceptions of the show were bad, boring, not informative, incomprehensible, subjective, and dull. Participants were asked to rate the paired positive-

negative items. The word chosen could receive one to three points depending on the participant's selection, while the opposing word received zero points. Points were totaled for both positive and negative perceptions. The maximum number of points the positive or negative perception scale could have was 18.

Perception of visuals

After viewing the show, participants were given a scale containing six semantic differential pairings of words. These pairings were designed to measure the positive-negative perceptions participants had of the show's visual elements. Positive perceptions of the visuals were good, entertaining, informative, comprehensible, supported the story, and complex. Negative perceptions of the visuals were bad, boring, not informative, incomprehensible, distracted from the story, and simple. Scoring was done as it was for the overall.

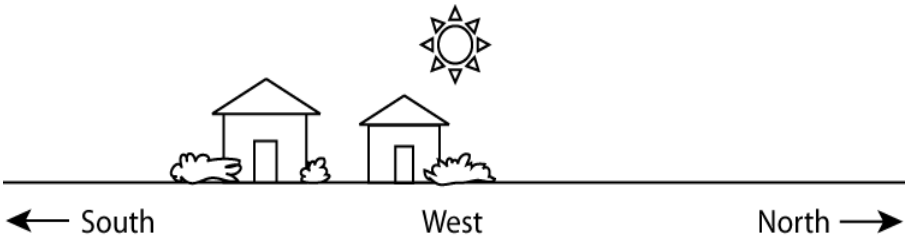
Knowledge of Maya Culture

Prior to viewing the show, participants were asked to answer five multiple-choice questions on the Maya. Participants were given one point for each question they answered correctly, with the exception of W*hat are the ancient Maya known for*? For this question there were three correct answers, participants were given 1/3 of a point for each correct answer on that question. The questions asked were:

- Where did the ancient Maya live (in today's terms)?
- When approximately was the height of the ancient Mayan culture?
- How did the ancient Maya live?
- What are the ancient Maya known for? (Check all that apply)
- What is the status of the Maya today?

Knowledge of Astronomy

Prior to viewing the show, participants were given five multiple-choice questions designed to measure knowledge of astronomy. These five questions were modified from the Astronomy Diagnostics Test version 2.0 developed by the Collaboration for Astronomy Education Research (CAER, 1999). The questions asked were:



- On September 22nd, in North America, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear two weeks later?
- As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
- When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?
- Where does the Sun's energy come from?

- Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth? Moon, Venus, Sun, and North Star listed in various orders.

What did the show communicate?

Post-program, participants were asked to list three main ideas learned about the stars, sun, and planets from watching the show and three key ways that the Maya used knowledge about astronomy in their daily lives. Data from these short answer questions were coded and compiled, to allow for comparison between groups.

Post-program, participants were asked to rate, on a seven-point scale, the extent to which they felt the show effectively communicated each of eight items related to Maya culture and astronomy. A one was not at all, while a seven was completely. The items rated were:

- Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.
- Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.
- Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.
- Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.
- By observing the patters of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.
- By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.
- Corn was so important to the Maya that it played a strong role in origin stories.
- The night sky represents the origin story of the Maya.

To allow for comparison, the items comprising these scales were asked on the delayed-post questionnaire as well.

Interest in learning more

After viewing the show, participants were asked to rate, on a seven-point scale, how interested they were in learning more about astronomy, indigenous knowledge, and Maya topics. There were four items to measure interest in astronomy, three items to measure interest in indigenous knowledge, and five items measuring interest in Maya topics. The items were designed as summated scales to measure interest in learning more for each of the concepts.

- Astronomy
    - Astronomy in general
    - Movement of the sun and planets
    - Understanding the night sky as observed from Earth
    - How stars, planets, and other astronomical elements affect life on Earth
- Indigenous Knowledge
    - Indigenous or native knowledge or ways of knowing
    - Connections between indigenous knowledge and Western science
    - The process of how native knowledge is created

- Mayan Topics
    - Maya culture and history
    - Maya architecture
    - The daily life of the Maya
    - Maya accomplishments in astronomy
    - The Maya calendar

Cronbach's alpha for the four items making up the interest in learning more astronomy scale was .891. Cronbach's alpha for the four items making up the interest in learning more about indigenous knowledge scale was .909. Cronbach's alpha for the five items making up the interest in learning more about Mayan topics was .905.

To allow for comparison, the items creating these scales were asked on the delayed-post questionnaire as well.

Interest, information seeking, and museum-going behaviors

The delayed post asked participants to rate, on a seven-point scale (where one indicated strongly disagree, and seven indicated strongly agree), how strongly they agreed with the following nine items:

Since seeing *Tales of the Maya Skies*, I:

- Felt more interested in Maya culture
- Felt more interested in astronomy
- Had more unanswered questions about the Maya or astronomy
- Have noticed things that remind me about the Maya more often in everyday life.
- Have paid more attention to things that remind me about the Maya topics when I've come across them in everyday life.
- Actively sought more information about the Maya (looking it up online, in a book or magazine, asking someone).
- Saw another planetarium show.
- Went to a museum to learn more about astronomy.
- Went to a museum to learn more about the Maya.

Demographics

A total of 233 matched pairs of instruments were completed. One hundred fifty-six (67.0%) were collected from those who viewed the full-dome version of the show (Chabot), 38 (16.3%) were collected from participants who viewed the large screen version of the show, and 39 (16.7%) who viewed the television version of the show. For those who chose to respond, 121 (54.8%) were female and 100 (45.2%) were male, 96 (44.2%) were age 30 to 49, 69 (31.8%) were age 50 and above, and 52 (24.0%) were age 18 to 29. Participants had a range of educational backgrounds, 24 (11.1%) stated they had a high school education or below, 57 (26.4%) stated they had attended community college, a technical school, or some college, 53 (24.5%) stated they had a bachelor's degree, 19 (8.8%) had attended some graduate school, and 63 (27.0%) stated they had a graduate degree.

One hundred forty-nine (63.9%) participants were white or Caucasian, 17 (7.7%) were Latino or Hispanic, 20 (9.1%) were Asian American or Pacific Islander, and 14 (6.4%) were black, five (2.3%) stated

they were Native American or Indigenous. Eight participants (3.4%) chose more than one ethnicity. One hundred thirteen (50.9%) participants were visiting Chabot or COSI for the first time, 113 (50.9%) stated they had seen a show in a planetarium before, while only three participants from Chabot (1.4%) stated they had previously seen *Tales of the Maya Skies*.

A participant was, therefore, most likely to be a white woman with a graduate degree, aged 30-49 who, though a first time visitor, had seen a planetarium show before this visit, but not *Tales of the Maya Skies*.

Question 1: Are there differences, based on the size of the screen the show is viewed on, in viewer perception of immersion?

The means of scores on the related scale reveal an interesting pattern. Overall mean scores for the full-dome were slightly to moderately positive (4.50 to 5.99). Overall means for the television were slightly negative to moderately positive (3.41 to 5.28). Large screen means were moderately negative to slightly positive (2.41 to 4.89). For both large screen and television, the strongest item mean was on *I was watching a program* (4.89 and 5.28 respectively) and the second strongest item means were for the item *I felt I was surrounded by images and sound* (4.25 and 4.82, respectively). For the full-dome, the strongest mean was on *I felt I was surrounded by images and sound* (5.99) followed by *I was in the middle of the experience* (5.67). It appears that for the large screen and the television, the sense is more about it being a sensory program than full immersion, whereas in the dome, the production does increase the sense of being in the middle of a sensory experience (See Table 1.1).

For the scale and for each item composing the scale, with the exception of *I was watching a program,* the full-dome group had a higher mean than the large screen and television group. The full-dome group had a standard deviation below one for the scale, and lower standard deviations than the large screen or television groups for all items except *I was watching a program* and *I was transported to a different place*. The television group had a higher mean than the large screen group for the scale and for all of the items composing the scale. The large screen group had lower standard deviations than the television group for the scale and all items composing the scale.

Table 1.1: Immersion scale, mean and standard deviation summated and per item, by screen size

	Dome (N=151)		LS (N=36)		TV (N=39)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Summated Immersion Scale	4.86	0.98	2.95	1.14	3.83	1.51	.000
I felt I was surrounded by images and sound	5.99	1.05	4.25	1.68	4.82	1.75	-
I was in the middle of the experience	5.67	1.12	3.41	1.57	4.18	1.85	-
I was watching a program	4.84	1.69	4.89	1.63	5.28	1.75	-
I was in a program	4.88	1.53	2.50	1.54	3.97	2.02	-
I was transported to a different place	4.98	1.51	2.42	1.42	3.90	2.04	-
My body was here but my senses were taken somewhere different	4.50	1.63	2.31	1.64	3.41	1.92	-
I was visiting a different place and time	4.81	1.65	2.72	1.75	3.79	2.13	-

An ANOVA was conducted using screen size as the independent variable and the summated mean of the immersion scale as the dependent variable. The results of the ANOVA indicate significant differences in mean between groups on the summated mean of the immersion scale, ($F(2, 223)= 48.49$, $p<.001$, $\eta^2 =.303$). Post hoc analysis (Bonferonni) indicates that the full-dome group had a mean significantly higher than the large screen group and the television group. The television group had a mean significantly higher than the large screen group. Table 1.1 shows the mean and standard deviation by each group, as well as for each item by group. P value is not given for the items as analysis was done at the scale level.

Question 2: Are there differences based on the size of the screen the show is viewed on, in viewer perception of the overall show and visuals of the show?

Perceptions of the show

As shown in Table 1.2, all three groups were clearly more positive than negative in their perceptions about the show. Participants who saw the full-dome presentation had both the highest mean score (11.77/18) on positive perceptions and the lowest mean score (1.03/18) on negative perceptions. Large screen had the lowest positive mean score (7.31/18) and highest mean negative score (2.94). The "net" scores (positive mean score, less negative mean score) reveal the distances between positive perceptions of the show. Full-dome had a 10.74 net positive score or 59.67% of potential positive score, television had a 7.92 net positive score (44.00%), and large screen had a 4.37 net positive score or 27.59% of potential positive.

A MANOVA was conducted using screen size as the independent variable and the summated positive and negative perception of the show semantic differential scales as the dependent variables. The results of the MANOVA indicated significant differences in mean scores between groups on the perceptions of the show ($F(2, 222)= 14.45$, $p<.001$, $\eta^2 =.115$). Post hoc analysis (Bonferonni) indicated that the full-dome group had significantly higher scores than the large screen group and also significantly higher scores when compared to the television group (Table 1.2). The MANOVA also indicates similar differences in mean between groups on the negative perceptions of the show ($F(2, 222)= 9.56$, $p<.001$, $\eta^2 =.079$). Post hoc analysis revealed that the full-dome had a significantly lower mean than the large screen group. Television also had a lower mean on negative perceptions when compared to large screen. There was no statistically significant difference between Dome and TV. Table 1.2 reflects the N used in this analysis.

Table 1.2: Positive and negative perceptions of the show, mean and standard deviation by screen size

	Dome (N=151)		LS (N=36)		TV (N=38)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the show	11.77	4.54	7.31	4.15	9.84	5.30	.000
Negative perceptions of the show	1.03	2.04	2.94	3.52	1.92	2.76	.000

Note: (1) Maximum possible amount of points per scale was 18 with a range 0-18.

Perception of visuals

Mean scores on perceptions of visuals were parallel to the overall perceptions of the show. Full-dome had both a higher mean on positive and a lower mean on negative than television (11.44 and 1.79 versus 9,05 and 3.08); television had a higher mean on positive and a lower mean on negative than did large screen. (Table 1.3) The net mean scores also had the same rank order, with full-dome having a

net positive score of 9.65 (53.61%), television having a net positive score of 5.97 (33.17%) and large screen having a very low net positive score of 1.28 (7.1%).

A MANOVA was conducted using screen size as the independent variable and the summated positive and negative perception of the show's visuals semantic differential scales as the dependent variables. The results of the MANOVA indicated significant differences in mean between groups on the summated mean of the positive perceptions of the show's visuals semantic differential scale ($F(2, 221)= 29.29$, $p<.001$, $\eta^2=.210$). Post hoc analysis (Bonferonni) indicated the full-dome group had significantly higher scores than both the large screen and the television groups. The television group had a significantly higher mean than the large screen group. The results of the MANOVA indicated significant differences in mean between groups on the summated mean of the negative perceptions of the show's visual semantic differential scale ($F(2, 221)= 19.24$, $p<.001$, $\eta^2=.148$). Post hoc analysis (Bonferonni) indicated the full-dome group had significantly lower scores than both the large screen and television groups. The television group had a significantly lower score than the large screen group.

Table 1.3: Perceptions of visuals, mean and standard deviation by screen size

	Dome (N=150)		LS (N=36)		TV (N=38)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the visuals	11.44	4.04	5.75	3.86	9.05	4.60	.000
Negative perceptions of the visuals	1.79	1.96	4.47	3.98	3.08	2.21	.000

Note: Maximum possible amount of points per scale was 18 with a range of 0-18.

In all three settings, overall satisfaction was higher than for satisfaction with visuals. This suggests the visuals were not as compelling as the overall effect of the production in all three settings. In terms of magnitude, the large screen visuals were considered the least positive (5.75) and the magnitude of difference between satisfaction overall and satisfaction with visuals was over a 1.5 difference (6-point scale). These data suggest the screen does make a difference in terms of visual and overall satisfaction.

Question 3: Are there differences, based on the size of the screen the show is viewed on, in viewer learning?

For the pre-measure, a series of multiple-choice questions were asked, five on Maya culture and five on astronomy. Each group had a mean score of less than three correct answers for the Maya culture questions (Table 1.4). The full-dome group had the highest mean (2.79/5) and second lowest standard deviation. The large screen group had the second highest mean (2.41/5) and lowest standard deviation. The television group had the lowest mean (2.09/5) and highest standard deviation.

An ANOVA was conducted using screen size as the independent variable and mean Maya culture knowledge score as the dependent variable. The results of the ANOVA indicated that there were statistical differences in incoming Maya knowledge between groups, based on screen size ($F(2, 230)= 5.75$, $p= .004$, $\eta^2=.048$). Post-hoc analysis indicated that the full-dome group mean was significantly higher than the television group mean. These data suggest that participants in the full-dome group had higher incoming knowledge of Maya culture than those in the television group. However, screen size had a very small effect on Maya culture knowledge.

Each group had a mean score of less than two questions answered correctly for the incoming astronomy knowledge questions (Table 1.4). The full-dome group had the highest mean (1.90/5) and highest

standard deviation. The large screen group had the second highest mean (1.66/5) and second highest standard deviation. The television group had the lowest mean (1.28/5) and lowest standard deviation.

An ANOVA was conducted using screen size as the independent variable and mean astronomy knowledge score as the dependent variable. The results of the ANOVA indicated that there were statistical differences in incoming astronomy knowledge between groups, based on screen size (F(2, 230)= 6.21, p= .002, η^2 =.051. Post-hoc analysis indicated that the full-dome group mean was significantly higher than the television group mean. These data suggest that participants in the full-dome group had higher incoming astronomy knowledge than those in the television group. However, screen size had a very small effect on astronomy knowledge.

Table 1.4: Maya culture knowledge and astronomy knowledge, mean and standard deviation by screen size

	Dome (N=156)		LS (N=38)		TV (N=39)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Maya Knowledge Items Correct	2.79	1.23	2.41	1.00	2.09	1.36	.004
Astronomy Knowledge Items Correct	1.90	1.02	1.66	0.99	1.28	0.89	.002

For the post-measure, a series of perceptual questions were asked, along with short answer questions, to attempt a proxy measure of knowledge. One set of questions was designed to obtain perceptions of intention in communication. Participants who saw the film in the full-dome theatre had the highest mean for each item asking what the film communicated, with the exception of *Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture*. The television group had the highest mean among groups for this item. The full-dome participants had the lowest standard deviation between groups for each item measuring what the film communicated. The television group had higher means than the large screen group for each item measuring what the film communicated with the exception of *By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons*. The large screen and television groups were mixed on the items in which they had lower or higher standard deviations (Table 1.5). It would appear that two messages were not affected by screen size. Both *Observing the heavens* and *Maya culture, life, cities, and architecture* were not statistically different among the three groups.

A MANOVA was run using screen size as the independent variable and the eight items measuring what the show communicated as the dependent variables. The results of the MANOVA indicated significant differences in mean scores between groups for six of the items measuring what the show communicated. Significant differences in mean between screen sizes were found for:

- *Corn was so important to the Maya that it played a strong role in origin stories* (F(2,222)= 5.41, p= .005 η^2 = .046). Post hoc analysis (Bonferonni) indicated that those in the full-dome group had significantly higher scores than those in the large screen group.

- *By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons* (F(2,222)= 3.64, p= .028 η^2 = .032). Post hoc analysis indicated that those in the full-dome group had significantly higher scores than those in the television group.

- *Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings* ($F(2,222)= 4.16$, $p= .017$ $\eta^2 = .036$). Post hoc analysis indicated that those in the full-dome group had significantly higher scores than those in the large screen group.

- *By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture,* ($F(2,222)= 6.61$, $p= .002$ $\eta^2 = .056$). Post hoc analysis indicated that those in the full-dome group had significantly higher scores than those in the large screen group

- *The night sky represents the origin story of the Maya*, ($F(2,222)= 7.04$, $p= .001$ $\eta^2 = .060$). Post hoc analysis indicated that those in the full-dome group had significantly higher scores than those in the large screen group, and those in the television group had significantly higher scores that those in the large screen.

- *Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life* ($F(2,222)= 3.55$, $p= .030$ $\eta^2 = .031$). Post hoc analysis indicated that those in the full-dome group had significantly higher scores than those in the large screen group.

Table 1.5: What did the show communicate, mean and standard deviation by screen size

	Dome (N=152)		LS (N=36)		TV (N=37)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Corn was so important to the Maya that it played a strong role in origin stories.	6.54	0.90	5.94	1.35	6.27	1.07	.005
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	6.51	0.81	6.22	1.10	6.08	1.36	.028
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	6.34	0.83	5.89	1.17	6.03	1.19	.017
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	6.24	1.22	5.36	1.64	5.81	1.64	.002
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	6.05	1.03	5.89	1.47	6.14	1.06	.627
The night sky represents the origin story of the Maya.	6.01	1.14	5.08	1.76	5.86	1.55	.001
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	5.95	1.16	5.31	1.72	5.78	1.46	.030
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	5.94	1.04	5.47	1.48	5.89	1.41	.104

Notes: (1) Items are shown in rank order by Dome mean; (2) items were rated on a seven point scale

Interest in learning more

All the means for the summated scales were slightly to moderately positive for both the full-dome and the television groups (Table 1.6). Two of the scales were slightly positive for the large screen (4.64 for indigenous knowledge and 4.74 for Maya topics). The full-dome group had a higher mean than the large screen group for each of the interest in learning more scales as did the television group. The television group had a higher mean than the full-dome group for the interest in learning more about Maya topics scale. The full-dome group had the lowest standard deviation per group for each scale, suggesting more uniform agreement across participants; the television group had a lower standard deviation than the large screen group for each scale.

A MANOVA was conducted using screen size as the independent variable and the interest scales as dependent variables. The results of the MANOVA indicate significant differences in mean scores between groups for the interest in learning more about indigenous knowledge ($F(2, 224)= 4.73$, $p=.010$, $\eta^2 = .041$), and interest in learning more about Maya topics scales ($F(2, 224)= 4.08$, $p= .018$, $\eta^2 = .035$). Post hoc analysis (Bonferonni) indicates that for the interest in learning more about indigenous knowledge scale, the full-dome group mean was significantly higher than the large screen group mean. Post hoc analysis indicates that for the interest in learning more about Maya topics scale, both the full-dome and the television group had significantly higher means than the large screen group.

Table 1.6: Interest in learning more summated scale, mean and standard deviation by screen size

	Dome (N=153)		LS (N=37)		TV (N=37)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Interest in learning more about astronomy summated scale	5.59	1.00	5.13	1.38	5.57	1.20	.071
Interest in learning more about indigenous knowledge summated scale	5.37	1.22	4.64	1.48	5.28	1.45	.010
Interest in learning more about Mayan topics summated scale	5.34	1.11	4.74	1.58	5.44	1.31	.018

Notes: Items making up each scale were rated on a seven-point scale.

Short Response

Stars, sun, and planets

Individuals were asked to identify the main ideas they learned about the stars, sun, and planets from the show. Participants were asked to identify three main ideas learned about the stars, sun, and planets from watching the show.

There were a total of 468 potential responses for this item from the full-dome group, 114 potential responses for the large screen group, and 117 potential responses from the television group. There were 79 (16.9%) of the full-dome group, 55 (48.2%) of the large screen group, and 42 (35.9%) of the television group left blank. The adjusted N from these missing cases is listed correctly in Table 1.6.

Participants' responses to this item were coded using emergent coding. A total of 19 codes were created. Three examples from the data are provided for the first ten codes based on the rank order of the full-dome group (Table 1.7).

Table 1.7: Top ten codes, frequency, and examples of main ideas about stars, sun, and planets learned from the show

Code	Rank Dome	Rank LS	Rank TV	Examples
Maya mythology: Stories of creation the Maya attached to the constellations, stars, and planets	1	2	1	Where and how the Earth was created from the Maya history Twins becoming sun and moon Orion stood for a turtle, Big Dipper was a owl
Calendar/time: Maya creation of a calendar using celestial positions or on the Maya using the position of the sun or planets to tell time	2	1	3	Mayans observed positions of planets to form calendar Counting days using sun They were the first people to track the days using a complex calendar
Eclipse: Maya learning to predict an eclipse or contained information that a new moon is necessary for an eclipse	3	4	4	The solar eclipse Solar eclipse can be seen only on a certain time at a certain place Total solar eclipses include the new moon
Position: Position of the planets and other celestial bodies including alignment of planets, orbit of planets, and the movement of planets	4	6	2	That the relationship between planets changes cyclically Impact of Earth rotation on visibility of planets They move in order and with respect to each other
Predicting seasons: Maya use of planets positions to predict seasons or responses that mention seasons in a very generic manner	5	8	8	To predict seasons Where the sun is aligned determines the seasons The seasons are determined by the tilt of the Earth's axis
Venus is important: Venus and it role in Maya culture/astronomy	6	3	4	Venus guides life cycles How Venus travels through the sky Venus was the main planet for Mayans
Agriculture: Maya use of celestial bodies to predict when to plan or harvest crops	7	5	10	The stars help the Maya to know when to harvest Rotation of sun/moon gave planting season The way farming and agriculture are affected (seasons)
Scientific observation: Scientific terminology used to describe the Maya ways of learning about the stars	7	11	6	Based on observed patterns Maya extrapolated out very accurate predictions Mayans knowledge of astrology based on tracking historical data The history of astronomical study
Not classifiable: Information provided was incomplete or incomprehensible, but still related to the show	9	12	7	They had amazing patience Need to be in right place at the right time to see it They started in B.C.

Culture/lifestyle: Lifestyle or culture of the Maya in a generic way	10	-	11	The origin of the Mayan culture Impacts daily life Importance of astrology to Mayan culture

Other less frequent responses included:

- Architecture which mentioned the Maya using the position of the planets/stars/sun to locate their buildings including temples;
- Connection between celestial bodies referring to the relationship between celestial bodies but lacking elements of position;
- Equator meaning no shadow at the equator two times per year;
- Corn comments lacking other elements but including Maya belief people were created from corn and corn as an important crop;
- Solstice referring to comments directly related to the Solstice twice a year;
- Zenith referencing the frequency of the zenith sun;
- Numbers: Maya use of base 20 number system; Maya creation of use of zero
- Related cultures: compared Maya astronomical knowledge to current knowledge, Maya culture to present day, and Maya use of calendar to present day;
- Equinox: frequency of equinox
- Not related to show

Table 1.8 displays the percent of the total responses per code, by screen size. This presentation reveals that for all three formats, over 50% of the responses were captured in the same categories of Maya mythology, Calendar/time, Eclipse, Position, and Predicting Seasons. The next three categories were also in the top five of one of the three formats. These findings suggest there was consistency across formats in terms of what was taken away as perceived learning.

Table 1.8: Percent of total per response by screen size for the three main ideas learned about the sun, stars, and planets, from watching the show

Code	Dome (n= 389)	LS (n= 59)	TV (n= 75)
Maya mythology	14.9	16.9	18.7
Calendar/time	11.6	18.6	12.0
Eclipse	10.5	10.2	10.7
Position	10.3	6.8	16.0
Predicting seasons	9.0	3.4	4.0
Venus is important	8.2	11.9	10.7
Agriculture	5.9	8.5	2.7
Scientific observation	5.9	1.7	9.3
Not classifiable	3.9	1.7	5.3
Culture/lifestyle	3.3	0.0	1.3
Architecture	3.1	5.1	1.3
Not related to show	2.8	0.0	1.3
Connection between celestial bodies	2.3	3.4	4.0
Equator	1.5	1.7	1.3
Corn	1.3	0.0	0.0
Solstice	1.3	0.0	0.0
Zenith	1.3	1.7	0.0
Numbers	1.0	0.0	1.3
Related to their (our) culture	0.7	3.4	0.0
Equinox	0.7	3.4	0.0

Note: Categories are shown in rank order of Dome group

Three key ways that the Maya used knowledge about astronomy in their daily lives

There were a total of 468 potential responses for this item from the full-dome group, 114 potential responses for the large screen group, and 117 potential responses from the television group. Out of these 52 (11.1%) of the full-dome group were left blank, 36 (31.6%) of the large screen group were left blank, and 36 (30.8%) of the television group were left blank.

Participants' responses to this item were coded into 13 emergent categories.

Table 1.9: Top 10 Codes, frequency, and examples of ways the Maya used knowledge about astronomy in their daily lives

Code	Rank Dome	Rank LS	Rank TV	Examples
Harvest crops/ agriculture	1	1	1	Planting and harvesting crops Farming and agriculture Planting, tending, harvesting
Calendar/ time	2	2	2	They marked time using a solar calendar The calendar formation (time keeping) Calendar system
Predicting seasons	3	3	3	Told them when the cold season was coming Forecast rain/drought They knew when the rains would come
Architecture	4	4	4	They used it in their architecture Orientation of buildings Used astronomy to construct temples to align with stars
Rituals/ celebrations	5	9	8	Determine the celebration time Timing of festivals Rituals
Religion	6	5	5	Validating religious beliefs They hold religious ceremonies that coincided with astrological events Their religious beliefs
Eclipse	7	5	6	To predict further things in the world such as the eclipse A solar eclipse occurs only once every 270 years Anticipate a solar eclipse
Mythology	8	5	0	As a way to communicate beliefs to the next generation Stories/folklore They used myths to explain the unknown
Movement/ alignment	9	10	0	Alignment of stars They measured the movement of the planets sun and stars Following the stars

All other codes had fewer than 10% of total responses in that screen format. The fourth most common rank code was that of Architecture, which included responses referencing the design and layout of cities, how and where buildings were constructed, and the alignment of buildings to the stars. Only Rituals (5.8% full-dome) and Religion (5.0% full-dome) had more than 5% of any screen's audience naming something in that code. Rituals was coded for responses referencing Maya knowledge of astronomy as guiding their celebrations or rituals. This code was given to responses that did not have an element of religion or mythology in the response. These statements were usually more generic in their description of how astronomy informed the Maya rituals or celebrations. Religion code referenced the Maya knowledge of astronomy as guiding their religious ceremonies or practices. This includes responses that contained the term "worship" and does not include responses that only reference celebration or rituals. Table 1.10 shows the percent of frequency responses for ways the Maya used knowledge and astronomy.

Table 1.10: Percent of total per response by screen size for three key ways the Maya used knowledge about astronomy in their daily lives

Code Received	Dome (N= 416)	LS (N= 78)	TV (N= 81)
Harvest crops/agriculture	38.5	42.3	35.8
Calendar/time	17.1	20.5	27.2
Predicting seasons	10.8	10.3	11.1
Architecture	7.8	7.7	7.4
Rituals/celebrations	5.8	2.6	2.5
Religion	5.0	3.8	4.9
Eclipse	3.8	3.8	3.7
Mythology	3.4	3.8	0.0
Movement/alignment	2.2	1.3	0.0
Not classifiable	2.2	3.8	3.7
Guided life	1.4	0.0	1.2
Math	1.0	0.0	0.0
Science	0.7	0.0	2.5

Note: Categories are shown in rank order by Dome group

Question 4: What changes in learning from the show do viewers express over time?

What did the show communicate?

Full-dome viewers who completed the delayed-post questionnaire (N=19), had notable differences in mean between immediate and delayed post for the items asking what the show communicated (Table 1.10). Immediately after viewing the show, viewers (those who ultimately responded to the delayed post questionnaire) rated *Corn was so important to the Maya that it played a strong role in origin stories* as the strongest message communicated. Two months later, these viewers rated *By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons* as the strongest message communicated, and the message on the importance of corn was rated second lowest. Overall, three of the items on the delayed-post had higher means than the same items on the immediate post, and five of the items had lower means than they had on the immediate post.

A paired samples t-test, an analysis comparing the change in mean from immediate to delayed post for those who completed both questionnaires, was run for each of the items in Table 1.10. The results of these analyses indicated that there was a significant difference between the immediate and delayed post means for the item *Corn was so important to the Maya that it played a strong role in origin stories*, $t(18)= 3.17$, p.=.005, and for the item *The night sky represents the origin story of the Maya* $t(17)= 2.85$, p.= .011. Both of these items had higher means on the immediate post questionnaire than on the delayed post questionnaire. Our findings suggest that for full-dome viewers who completed both the immediate and delayed post questionnaire, the messages on the Maya's use of astronomy for creating calendars and positioning buildings were viewed in hindsight as being stronger messages communicated by the film than the messages on the importance of corn and the origin story of the Maya.

Table 1.10: What did the show communicate, mean and standard deviation for immediate post and delayed post for full-dome viewers

	Immediate Post Dome (N=19)		Delayed Post Dome (N=19)		
	$\bar{X}$	SD	$\bar{X}$	SD	P value
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	6.53	0.70	6.37	0.90	.482
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	6.32	0.67	6.37	0.76	.772
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	5.89	1.05	5.95	1.13	.853
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	5.84	1.07	5.95	1.18	.630
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	6.21	0.98	5.95	1.35	.235
Corn was so important to the Maya that it played a strong role in origin stories.	6.68	0.48	5.89	1.33	.005
The night sky represents the origin story of the Maya.	6.22	1.17	4.94	1.98	.011
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	6.06	1.35	5.00	2.20	.078

Note: Items presented in descending order of delayed post mean

Large screen show viewers who also completed the delayed-post questionnaire (N=4) had notable differences in mean between immediate and delayed post for the items asking what the show communicated (Table 1.11). Immediately after viewing the show, viewers (those who ultimately responded to the delayed post questionnaire) rated *Corn was so important to the Maya that it played a strong role in origin stories* as the strongest message communicated. Two months later, these viewers rated *Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy* as the strongest message communicated and the message on the importance of corn was rated lowest. Overall, three of the items on the delayed-post had higher means than the same items on the immediate-post, four of the items had lower means than they had on the immediate-post, and one, *The night sky represents the origin story of the Maya*, remained unchanged.

A paired samples t-test was run for each of the items in Table 1.11. The results of these analyses indicated that there was a significant difference for large screen show viewers who completed the immediate and delayed post questionnaires, between the immediate and delayed post means for the item *Corn was so important to the Maya that it played a strong role in origin stories*, $t(3)= 3.46$, p.=.041. As with the findings from the full-dome group, over time, the message on the importance of corn was not the strongest message communicated, and indeed ended up as one of the weakest messages communicated.

Table 1.11: What did the show communicate, mean and standard deviation for immediate post and delayed post for large screen viewers

	Immediate Post LS (N=4)		Delayed Post LS (N=4)		P Value
	$\bar{X}$	SD	$\bar{X}$	SD	
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	4.00	2.16	5.00	2.71	.092
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	4.00	2.16	4.75	2.50	.215
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	5.00	1.83	4.50	2.65	.391
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	3.75	2.22	4.25	2.22	.495
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	5.00	1.15	4.00	2.16	.353
The night sky represents the origin story of the Maya.	3.75	2.50	3.75	2.22	1.00
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	4.50	3.00	3.75	2.06	.444
Corn was so important to the Maya that it played a strong role in origin stories.	5.50	1.73	3.50	2.08	.041

Note: Items presented in descending order of delayed post mean

Television viewers who completed both the immediate- and delayed-post questionnaires (N=3), rated seven of the eight items higher on the delayed-post than they had on the immediate-post. The item on the importance of corn had a mean of 7.00 (out of 7.00) on the delayed-post. Dependent samples t-test indicated no significant changes of television viewer means between immediate- and delayed-post items.

Short Response Items

Viewers were asked to list the main ideas they learned about the stars, sun, and planets from watching the show. A total of 27 codes were given to responses from full-dome viewers, six codes to responses from large screen viewers, and four codes to responses from television viewers. The most frequent code given to full-dome group responses was the mention that the Maya were astronomers or used observation of celestial bodies, followed by responses suggesting participants could not recall or did not feel that they had learned anything from the show, followed by responses mentioning generically that these celestial bodies informed Maya culture. The most frequently coded response for the large screen group was not remembering or feeling that they had not learned anything from the show, followed by a generic reference to the stars, sun and planets informing Maya culture, followed by a response suggesting the Maya were astronomers. The television group had four responses, all with one occurrence each: culture, didn't learn/don't remember, mythology, and a response referencing the sun's position. This order is in contrast to the full-dome group order from the immediate post, which was mythology, followed by calendar/time, and then eclipse.

These data suggest that for those who completed the delayed post questionnaire many were unable to recall specific things they felt they had learned about the stars, sun and planets from watching the show, and that those who did recall learning something often generically mention these having an effect on Maya culture.

Table 1.12: Percent of response per code by screen size

Code Received	Dome (N= 27)	LS (N= 6)	TV (N= 4)
Astronomers/Observation of sky	15	17	0
Didn't learn anything/Don't remember	15	50	25
Culture (generic)	11	33	25
Mythology	11	0	25
Calendar/time	11	0	0
Agriculture	7	0	0
Off topic/Not related to show	7	0	0
Guided daily life	4	0	0
Solstice	4	0	0
Suns' position	4	0	25
Astrology/Astronomy	4	0	0
Venus' cycle	4	0	0
Seasons	4	0	0

Note: Codes listed in descending order by Dome percent

Viewers were asked to provide a short response to what they learned from the show about key ways that the Maya used knowledge about astronomy in their daily lives. A total of 34 codes were given to responses from full-dome viewers, seven codes to responses from large screen viewers, and seven codes to responses from television viewers. The most frequent code given to responses from full-dome viewers was that astronomy informed Maya agriculture practices, followed by informed the Maya calendar and then Architecture. This order held for the large screen group; the television group had seven codes, each with one response. This order is almost identical to the immediate-post order for all three groups, which was Agriculture, followed by Calendar/time and Architecture as the fourth most frequently coded response. These data suggest for viewers who completed the delayed-post questionnaire, the Maya use of astronomy to inform their agriculture practices, calendar creation, and architecture (placement of buildings) were the messages that had a longer lasting impact or ability to be recalled.

Table 1.13: Percent of response per code by screen size

Code Received	Dome (N= 34)	LS (N= 7)	TV (N= 7)
Agriculture	41	43	14
Calendar/time	30	14	14
Architecture	12	14	14
Religion	6	0	14
Astronomy	3	0	14
Mythology	3	0	14
Solstice	3	0	0
Don't remember	3	14	0
Seasons	0	14	14

Note: Codes listed in descending order by Dome percent

Question 5: Are there differences over time, based on screen size, in viewers' interests and behaviors related to the topics covered in the show?

Data from the delayed-post items on viewer follow-up interest and behaviors related to topics of the show reveal a similar pattern across groups (Table 1.14). Each item is rated at middle to low levels of agreement. The items asking about interest in topics covered by the show are rated highest, these are followed by the items on attention and information seeking related to show topics, and items with the lowest means are those asking about follow-up behaviors in museums. This would suggest that while viewers had moderate levels of interest across screen size following viewing the show, very little of this was acted upon through information seeking or engaging in related behaviors to learn more. An ANOVA was run using screen size as the independent variable for each item; results indicated there were no significant differences between screen sizes for the items.

Table 1.14: Interest, information seeking, and museum going behaviors, mean and standard deviation by screen size

	Dome (N=19)		LS (N=4)		TV (N=3)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Felt more interested in Maya culture.	4.53	1.90	3.00	1.83	4.67	1.16
Felt more interested in astronomy.	4.39	1.85	4.25	2.22	4.33	3.06
Had more unanswered questions about the Maya or astronomy.	4.00	2.16	2.25	1.89	3.00	2.65
Have noticed things that remind me about the Maya more often in everyday life.	3.79	1.99	2.50	2.38	2.00	1.73
Have paid more attention to things that remind me about the Maya topics when I've come across them in everyday life.	3.79	1.81	2.25	1.89	2.00	1.73
Actively sought more information about the Maya (looking it up online, in a book or magazine, asking someone).	3.11	2.21	2.25	1.89	2.33	2.31
Saw another planetarium show.	3.00	2.30	2.75	2.87	1.33	0.58
Went to a museum to learn more about astronomy.	2.89	2.11	2.00	1.41	1.33	0.58
Went to a museum to learn more about the Maya.	2.21	1.87	2.00	1.41	1.33	0.58

Note: Items are presented in descending of Dome group mean.

Interest Scales

Viewers completing the delayed-post questionnaire were asked to complete items creating the scales measuring interest in learning more about astronomy, indigenous knowledge, and Maya culture. The summated scale scores were compared to viewer response to the same scales on the immediate post. Full-dome viewers who completed the delayed-post questionnaire (Table 1.15) had lower mean scores for each of the three scales. Dependent samples t-test indicated this difference was significant for interest in astronomy, $t(18)=3.68$, p=.002, and for interest in indigenous knowledge $t(17)= 2.37$, p= .030

Table 1.15: Dome group mean and standard deviation for interest in astronomy, indigenous culture, and Maya culture scales

	Immediate Post Dome (N=19)		Delayed Post Dome (N=19)		P value
	$\bar{x}$	SD	$\bar{x}$	SD	
Interest Astronomy	6.00	1.00	5.26	1.01	.002**
Interest Indigenous	5.18	1.54	4.61	1.71	.030*
Interest Maya Culture	5.14	1.12	4.85	1.48	.394

Large screen viewers who completed the delayed-post questionnaire displayed a similar pattern as the Dome group, with each scale having a lower mean on the delayed-post than on the immediate-post (Table 1.16). These differences were not significant.

Table 1.16: Large screen group mean and standard deviation for interest in astronomy, indigenous culture, and Maya culture scales

	Immediate Post LS (N=4)		Delayed Post LS (N=4)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	
Interest Astronomy	5.69	0.89	5.56	1.01	.664
Interest Indigenous	4.63	2.09	4.00	2.45	.797
Interest Maya	4.95	2.51	3.85	2.39	.682

Television viewers who participated in the delayed post had higher means on the delayed post for each of the three scales (Table 1.17). These differences were not significant.

Table 1.17: TV group mean and standard deviation for interest in astronomy, indigenous culture, and Maya culture scales

	Immediate Post TV (N=3)		Delayed Post TV (N=3)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	
Interest Astronomy	4.83	1.88	5.42	2.13	.704
Interest Indigenous	4.83	1.26	5.17	0.29	.742
Interest Maya	4.80	2.11	4.87	0.31	.960

Discussion: Study 1

These findings provide evidence supporting the theoretical speculation that full-dome/giant screen theater is a more effective medium at conveying scientific concepts and inspiring an interest to learn than movie theater style screen or television. In general, *Tales of the Maya Skies* was more successful in achieving the desired outcomes in the full-dome theatre than in the other formats. These findings suggest that those who viewed the full-dome version of the show experienced a greater sense of immersion. Theoretically, this sense of immersion is necessary to create the impacts of learning and enjoyment by viewers. Our findings support this; we found greater positive perceptions of the show and visuals in the full-dome group, and full-dome viewers felt the show communicated all the measured messages at higher levels than the large screen and television groups. This would suggest that educational films developed for full-dome experiences have an opportunity to take advantage of the immersive nature of a dome, increasing the likelihood that viewers will identify the messages intended in the experience.

One caveat must be that the film tested was designed for the full-dome environment, and the only adaptation made for the other environments was modifying to the rectangular aspect-ratio and size; all timing, narration, and visuals remained the same. The researchers comparing the screens noted that the flat-screen versions of this dome film visually moved more slowly than would film that has been specifically created for flat screens.

All three screen formats led to recognition of desired messages and positive satisfaction. Consistently, the full-dome theatre was the strongest, followed by the television screen, and with the large screen being the least effective. The dome appears to create a more immersive experience for viewers, as measured by the immersion scale, communicates concepts better, and creates a greater interest in learning more when compared to a large screen.

The above two findings imply that design differences for the formats can relate to the sense of immersion. The findings suggest that which senses are engaged in the immersive experience does vary: those in the dome felt surrounded by images and sounds. Those in the flat screen versions also reported they felt "surrounded," but the surround referred to audio which made them feel they were "in" the experience. In conducting the analysis, it was noted that visitors to all three formats had a difficult time attempting to separate "components" of the experience. Story, visuals, overall impressions, message, and sound, all blend as a single experience for most visitors to *Tales of the Maya Skies*.

In open-ended questions, visitors identified specific astronomy concepts they believed they learned in the viewing. Full-dome and TV groups were much more likely to mention scientific concepts, such as observation. All groups, however, revealed an interesting phenomenon: the cultural narrative took over the show's story so that the most frequently mentioned messages about the astronomy (phrased as "the sun, stars, and planets") were still connected to the cultural narrative, framed to be about Maya "mythology" rather than Maya use of science—science was overtaken by the cultural narrative. This was not apparent as a goal of the production, but was rather one of four story lines.

Delayed-post findings reveal further interesting patterns about viewer learning; however, these should be interpreted with caution given the low sample sizes. These results suggest that the messages from the film most strongly recalled by viewers seem to change over time, with viewers feeling that the story of the importance of corn was a key message immediately after viewing the film, but with that message fading away over time. After two months, viewers instead seemed to connect the show to its more central message of Maya abilities and achievements as astronomers and the role of astronomy in daily life. Delayed-post data also indicated that there was not a striking increase in interest or information-seeking behaviors among visitors following their viewing of *Tales of the Maya Skies*.

An interesting question arises in considering that viewers of the television presentation had more positive outcomes than viewers of the large screen: Why? In observing participants watching the different versions, the researchers noted there was attrition in the audience and behaviors consistent with general movie-going audiences in the large screen screenings (e.g., whispering between group members), whereas these behaviors were not nearly as present in the full-dome or television conditions. What do we make of the consistent finding that television viewers felt a greater sense of immersion, had greater positive perception of the show and visuals, and identified more strongly with the messages communicated by the show than the large screen group? This would suggest that size is not the only factor in determining the level of immersion. Perhaps distance from the screen is equally

important. Whereas television viewers all sat very close to the television out of necessity, large screen viewers were able to spread out, increasing the distance between their placement and the screen. This may allow for peripheral distraction that prevents the sense of immersion felt by full-dome and television viewers. It is possible that the lower sense of immersion can be attributed to the mindset that one has when watching a show on a large screen and opposed to on a television. Televisions in households are a common way to lose oneself in sound and image. Large screen movie theaters are a more social experience, taking place in a setting that has different social norms and expectations than when one is watching television. Perhaps this difference in mindset contributed to the sense of immersion participants felt.

Another possible explanation for these observations is that television is considered to have educational purposes as well as entertainment, while movies are about entertainment. If this is the case, it might explain why parents were quieting children during the television showings and talking with their children in the large screen showings. This is also consistent with some of the emerging findings on uses of various technologies: people respond to technologies by defining how/when they are used for themselves. This suggests that film versions may be viewed differently by visitors because films are considered entertainment, necessitating a different way of approaching story and production than for either full-dome theaters or television. This conjecture should be tested using film meeting standards for each of the three formats to determine if there is a societal expectation around each of the formats. A second line of inquiry that could emerge from this observation is about the value of intentionality in developing educational media for different formats based on expectations of the format.

Results: Study 2 – The Cultural Wrapper

Questions

The overarching research question for this component of the study was "What is the influence of the cultural wrapper one comes in with have on learning?" For this study, the concept of cultural wrapper refers to the approach of focusing the production on the telling a story of astronomy and astronomical achievements through a cultural lens of the Maya people. The emerging research question, then, asks about this wrapper in relation to the cultural background, cultural identity, heritage and proximity to a cultural subset that the visitor would bring with them. It is supposed that the degree of one's personal connection to this culture may influence learning or enjoyment. Another possibility is that the cultural proximity to Maya culture by Maya descendents and Mexican immigrants could be amplified by having the production in Spanish rather than English. Further, evidence from the front-end evaluation (Stein, 2007) indicated that many members of the local Hispanic community had family origins and ties to communities of Mexico, Guatemala, and Honduras, and felt personal connections with the Maya people.

To answer this question, seventeen sub-questions related to aspects of viewers' cultural connections to the cultural wrapper of the show as the independent variable were addressed:

1) Are there differences, based on the language of the show, in incoming viewers self-reported interest in Maya culture, knowledge of Mayan culture, connection to Maya culture, connection to astronomy, knowledge of Mayan culture, and knowledge of astronomy?
2) Are there differences, based on the language of the show, in viewer perceptions of the overall show, visuals of the show, and what they liked about the show?
3) Are there differences, based on the language of the show, in viewer learning?
4) Are there differences, based on connection to Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
5) Are there differences, based on connection to Mayan culture, in viewer learning?
6) Are there differences, based on prior knowledge of astronomy, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
7) Are there differences, based on prior knowledge of astronomy, in viewer learning?
8) Are there differences, based on interest in Maya culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
9) Are there differences, based on interest in Maya culture, in viewer learning?
10) Are there differences, based on interest in astronomy, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
11) Are there differences, based on interest in astronomy, in viewer learning?
12) Are there differences, based on age, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
13) Are there differences, based on prior knowledge of Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?
14) Are there differences, based on prior knowledge of Mayan culture, in viewer learning?
15) Are there differences, based on age, in viewer learning?
16) Are there differences, based on sex (male or female), in viewer perception of the overall show, visuals of the show, and what they liked about the show?
17) Are there differences, based on sex (i.e. male or female), in viewer learning?

Measurements

Independent variables: Language, self-reported interest in Maya culture, self-reported knowledge of Maya culture, connection to Maya culture, connection to astronomy, knowledge of Maya culture, knowledge of astronomy, age, and sex

Language

Language was determined by the format of the film viewed. Two formats were available: English language and Spanish language. Language was the only difference between the films, the visuals and narrative remained the same.

Self-report interest in Maya culture

Participants were asked to rate their level of interest on a seven-point scale (1= none and 7= a lot) on four items related to Mayan topics:

- Mayan astronomy
- Ancient Mayan culture
- Daily life of the ancient Mayan people
- Present-day Mayan culture

Participants were also asked to rate on a seven-point scale (one representing none, and seven representing a lot) their knowledge of the same four items listed above. Analysis was at the item level, with comparison between groups and comparison between self-reported interest and knowledge.

Connection to Mayan culture

Participants were asked to rate their level of agreement on a seven-point scale (one representing Strongly Disagree, and seven representing Strongly Agree) with four items measuring connection to Mayan culture:

- I feel personally connected to the Maya.
- I believe the Maya have contributed much to our human heritage.
- We have much to learn from the Maya.
- I feel it is important that people learn about Maya heritage.

The four items making up the connection to Mayan culture scale had an alpha reliability of .769. Analysis was at the summated scale level and between groups, with three groups being created reflecting low, medium, and high connection to Mayan culture.

Knowledge of Mayan culture

Participants were asked to answer five multiple-selection questions on the Maya. Participants were given one point for each question they answered correctly, with the exception of W*hat are the ancient Maya known for*? For this question there were three correct answers, so participants were given 1/3 of a point for each correct answer on that question. Analysis was at the summated overall mean level and between groups, with three groups being created reflecting low, medium, and high knowledge of Mayan culture. The questions asked were:

- Where did the ancient Maya live (in today's terms)?
- When approximately was the height of the ancient Mayan culture?
- How did the ancient Maya live?
- What are the ancient Maya known for? (Check all that apply)
- What is the status of the Maya today?

Self- report connection to astronomy

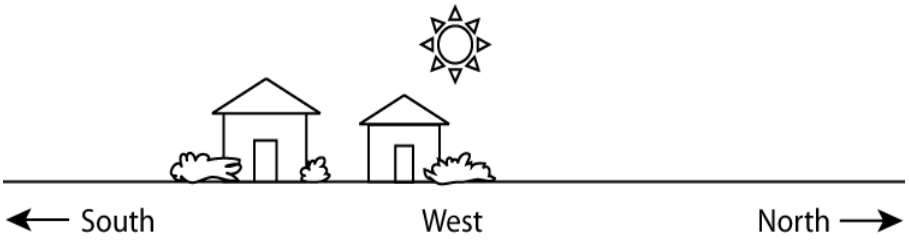
Participants were asked to rate their level of agreement on a seven-point scale (where one represented Strongly Disagree, and seven represented Strongly Agree) with how much they wanted to learn more about. Items were:

- I think astronomy is a fascinating subject.
- I like learning about the stars.
- I like to follow current news about space.
- I would call myself an amateur astronomer.

The four items making up the connection to astronomy scale had an alpha reliability of .769. Analysis was at the summated scale level and between groups, with three groups being created reflecting low, medium, and high connection to astronomy.

Knowledge of Astronomy

Participants were given five multiple-selection questions designed to measure knowledge of astronomy. These five questions were modified from the Astronomy Diagnostics Test version 2.0 developed by the Collaboration for Astronomy Education Research (CAER, 1999). Analysis was at the summated overall mean level and between groups, with three groups being created reflecting low, medium, and high knowledge of astronomy. The questions asked were:



- On September 22nd, in North America, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear two weeks later?
- As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?
- When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?
- Where does the Sun's energy come from?
- Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth? Moon, Venus, Sun, and North Star listed in various orders.

Age

Participants were asked to provide their year of birth on the pre-show questionnaire. This was then converted into age. Because of variance, rather than use age as a scale, it was determined that categorical data would reveal stronger information. Thus three age categories were coded for analysis: 18-29 years old, 30-49 years old, and 50 years old and above.

Sex

Participants were asked to circle if they were male or female on the pre-show questionnaire.

Dependent Variables: Perceptions of the show, Viewer learning

There were two broad dependent variables: perceptions of the show and viewer learning. Perceptions of the show were further divided into perceptions of the overall show, perceptions of the visuals, and what individuals liked about the show.

Perception of the overall show

After viewing the film, participants were given a scale containing six semantic differential pairings. These word pairings were designed to measure the positive-negative perceptions participants had of the film in general. Positive perceptions of the show were: good, entertaining, informative, comprehensible, objective, and stimulating. Negative perceptions of the show were bad, boring, not informative, incomprehensible, subjective, and dull. Participants were asked to rate the paired positive-negative items using a six-point semantic differential. The word chosen could receive one to three points depending on the participants' selection, while the opposing word received zero points. The points were then totaled for both positive and negative perceptions. The maximum number of points the positive or negative perception scale could have was 18. Analysis was at the summated scale level for both positive and negative scales, with comparison between groups.

Perception of visuals

After viewing the film, participants were given a scale containing six semantic differential pairings. These word pairings were designed to measure the positive-negative perceptions participants had of the film's visual elements. Positive perceptions of the visuals were good, entertaining, informative, comprehensible, supported the story, and complex. Negative perceptions of the visuals were bad, boring, not informative, incomprehensible, distracted from the story, and simple. Participants were asked to rate the paired positive-negative items using a six-point semantic differential. The word chosen could receive one to three points depending on the participants' selection, while the opposing word received zero points. The points were then totaled for both positive and negative perceptions of the visuals. The maximum number of points the positive or negative perception of the visuals scale could have was 18. Analysis was at the summated scale level for both positive and negative scales, with comparison between groups.

Liked about the movie

After viewing the show, participants were asked to rate, on a seven-point scale (where one represented Not at all, and seven represented Completely), how much they liked four different elements of the show. Analysis was at the item level with comparison between groups. The four elements participants were asked to rate were:

- A story about the Maya and their culture, including their knowledge and use of astronomy.
- A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society.
- A story of Maya folklore and mythology and how that relates to Maya culture.
- A story about astronomical concepts and how the Maya learned these concepts.

Viewer Learning

Post-program, participants were asked to rate, on a seven-point scale, the extent to which they felt the show effectively communicated each of eight items related to Maya culture and astronomy. The items rated were:

- Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.
- Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.
- Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.
- Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.
- By observing the patters of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.
- By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.
- Corn was so important to the Maya that it played a strong role in origin stories.
- The night sky represents the origin story of the Maya.

The primary story told by the show

Post-program, participants were given four descriptions of the film and asked to rate how much they felt the film told the story in each description. Participants were given 100 points total and asked to distribute these points among the four descriptions based on how well they felt the film told that specific story. There was no minimum set for the amount of points participants could give each description, the total among the four descriptions could not exceed 100. The descriptions were analyzed individually, with comparison between groups. The descriptions given were:

- A story about the Maya and their culture, including their knowledge and use astronomy.
- A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society.
- A story of Maya folklore and mythology and how that relates to Maya culture.
- A story about astronomical concepts and how the Maya learned these concepts.

Partially open-questions

Post-program, participants were asked to list three main ideas learned about the stars, sun, and planets from watching the show and three key ways that the Maya used knowledge about astronomy in their daily lives. Data from these short answer questions were coded and compiled, to allow for comparison between groups.

Demographics

A total of 179 matched pairs of instruments were completed. One hundred fifty-six (87.2%) of the questionnaires were collected from participants who viewed the English language version of the film, 23 (12.8%) were collected from participants who viewed the Spanish language version of the film. For those who chose to respond, 88 (52.7%) were female and 79 (47.3%) were male, 75 (42.9%) were age 30 to 49, 59 (33.7%) were age 50 and above, and 41 (23.4%) were age 18 to 29. Participants had a range of educational backgrounds, 10 (6.1%) stated they had a high school education or below, 46 (28.2%) stated they had attended community college, a technical school, or some college, 40 (24.5%) stated they had a bachelor's degree, 18 (10.1%) had attended some graduate school, and 49 (30.1%) stated they had a graduate degree.

Eighty-four (50.3%) of the participants were white or Caucasian, 36 (21.6%) were Latino or Hispanic, 19 (10.6%) were Asian American or Pacific Islander, and 13 (7.3%) were black or African American. Six participants (3.4%) chose more than one ethnicity. One hundred twelve (66.7%) participants were visiting Chabot for the first time, 128 (76.2%) stated they had seen a show in a planetarium before, while 5 (3.0%) stated they had previously seen *Tales of the Maya Skies*.

A participant was, therefore, most likely to be a white woman with a graduate degree, age 30 to 49, viewing the English language version of the show, and though a first time visitor to Chabot had viewed a planetarium show in the past, but not *Tales of the Maya Skies*.

Question 1: Are there differences, based on the language the show was viewed in, in the incoming viewer self-reported interest in Maya culture, knowledge of Mayan culture, connection to Maya culture, connection to astronomy, and knowledge of astronomy?

Interest in Maya Culture

The mean scores on the items related to participants' incoming interest in Maya culture (Table 2.1) suggest that most participants had moderate to high levels of prior interest in Maya culture. The means reveal that viewers of the Spanish language version had a higher prior interest in Maya culture than English language viewers. Viewers of the Spanish language version of the show had lower standard deviations for three of the four items. Standard deviations are moderately similar with the exception of the item on present-day Maya culture, in which Spanish language viewers had a much smaller standard deviation.

Independent samples t-tests were run by film viewed for each item on self-reported interest in Maya topics. Viewers of the Spanish language film had significantly higher self-reported interest for each item than those in the English language viewing group. Differences in mean for interest were significant for Mayan astronomy ($t(169)= -2.82$, $p= .005$); for the ancient Mayan culture item ($t(169)= -2.41$, $p=.017$); for daily life of the ancient Maya people ($t(169)= -3.23$, $p= .001$); and for present day Mayan culture ($t(168)= -6.50$, $p= .000$). There were fewer cases for this analysis than the self-reported interest analysis due to cases missing data.

Table 2.1: Pre-show self-reported interest in Maya culture English vs. Spanish version

	English Film (N=149)		Spanish Film (N=22)		P value
	$\bar{x}$	SD	$\bar{x}$	SD	
Mayan astronomy	5.22	1.33	6.09	1.51	.005
Ancient Mayan culture	5.31	1.42	6.09	1.41	.017
Daily life of the ancient Maya people	5.21	1.47	6.27	1.16	.001
Present-day Mayan culture	5.04	1.53	6.55	0.91	.000

Note: Items were measured on a seven point rating scale. A one was "None" a seven was "A lot"

Knowledge of Maya Culture

The mean scores for self-reported knowledge of Maya culture suggest that participants felt they have a lower knowledge of Maya culture than they do interest in Maya culture. All items had means below four (negative) with the exception of Spanish language viewers on the item *Daily life of the ancient Maya people*. Spanish language viewers rated their knowledge at higher levels than English language viewers on each item. English language viewers of the show had lower standard deviations on each item suggesting a more consistent response.

Independent sample t-tests were run by film viewed for each item on self-reported knowledge of Maya culture. Table 2.2 shows viewers of the Spanish language version of the show rated their knowledge of Mayan topics significantly higher for each item, than English language viewers of the show. Differences in mean for interest were significant for Mayan astronomy ($t(166)= -2.85$, p= .010); for the ancient Mayan culture item ($t(167)= -2.92$, p=.004}; for daily life of the ancient Maya people ($t(167)= -3.59$, p= .001); and for present day Mayan culture ($t(166)= -4.35$, p= .000).

Table 2.2: Pre-film self-reported knowledge of Mayan culture

	English Film (N=153)		Spanish Film (N=21)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	
Mayan astronomy	2.46	1.31	3.48	1.63	.010
Ancient Mayan culture	2.88	1.43	3.82	1.82	.004
Daily life of the ancient Maya people	2.73	1.42	4.23	1.85	.001
Present-day Mayan culture	2.30	1.45	3.73	1.83	.000

Note: Items were measured on a seven point rating scale. A one was "None" a seven was "A lot"

Connection to Maya Culture

Overall, participants rated each item on their connection to Maya culture at slightly positive levels, with the exception of feeling personally connected to the Maya. Items had rather high standard deviations. These high standard deviations suggest that groups of participants may have rated their connection as much higher or lower than the mean, suggesting a bi-modality in the data. English language viewers had a higher mean and a higher standard deviation on the summated connection to Maya culture scale. English language viewers had a higher mean and lower standard deviation for each item making up the scale, with the exception of *I feel personally connected to the Maya*. Our findings suggest that both Spanish language and English language viewers have low feelings of connection to Maya culture.

Table 2.3: Connection to Maya culture, summated scale and items mean and standard deviation

	Total (N=176)		English Film (N=154)		Spanish Film (N=22)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Self-reported Connection to Maya culture Scale	4.64	2.87	4.67	2.99	4.26	2.28	.540
I feel personally connected to the Maya.	2.85	1.83	2.66	1.68	4.00	2.25	-
I believe the Maya have contributed much to our human heritage.	4.76	1.66	4.77	1.50	4.36	2.48	-
We have much to learn from the Maya	4.94	1.72	4.97	1.53	4.41	2.67	-
I feel it is important that people learn about Maya heritage.	4.95	1.70	5.01	1.49	4.27	2.68	-

Note: Items were measured on a seven point rating scale.

An independent sample t-test did not indicate a significant difference between groups of the summated connection to Maya culture scale ($t(174)= 0.615$ p=.540). English language viewers had a slightly higher mean on the summated scale. P values are not given for each item in the table as analysis was done at the scale level.

Connection to Astronomy

Overall, participants had positive scores on the items making up the connection to astronomy scale (Table 2.4), with the exception of *I would call myself an amateur astronomer*. Both English language and Spanish language viewers rated *I think astronomy is a fascinating subject* as the highest item for this scale. Viewers of the English language version of the show had a higher mean for each item on the scale, with the exception of *I would call myself an amateur astronomer*. Viewers of the English language version of the show had a lower standard deviation for each item on the scale. Our findings suggest that English language viewers had a much more positive connection to astronomy than Spanish language viewers.

An independent samples t-test indicated significant differences between film viewed for the summated mean on the connection to astronomy scale ($t(174)= 3.79$, p=.020). English language viewers had a significantly higher mean score than Spanish language viewers on the scale. English language viewers had a lower standard deviation for the summated scale mean as well.

Table 2.4: Connection to astronomy, summated scale and item means and standard deviation

	Total (N=176)		English Film (N=154)		Spanish Film (N=22)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Self-reported Connection to Astronomy	4.95	1.31	5.04	1.11	4.00	1.99	0.25
I think astronomy is a fascinating subject	5.95	1.57	6.18	1.18	4.27	2.68	-
I like learning about the stars	5.77	1.54	5.98	1.19	4.14	2.51	-
I like to follow current news about space	5.06	1.81	5.20	1.67	3.86	2.36	-
I would call myself an amateur astronomer	3.01	1.85	2.82	1.77	3.73	1.87	-

Note: (1)Items were measured on a seven-point rating scale with one “Strongly Disagree” and seven “Strongly Agree”

Maya Knowledge Questions

Overall, participants earned approximately half (55.8%) of the points possible for these items. Spanish language viewers of the film had a slightly higher mean and lower standard deviation than English language viewers for the number of Maya knowledge questions answered correctly. Pearson correlations were run to determine the level of correlation between self-reported interest and knowledge of Maya topics and the number of correct answers participants had on the Maya knowledge questions. Self-reported interest in Maya topics was not significantly correlated with the number of questions answered correctly for the Maya knowledge questions, r=-.057, p=.452. Self-reported knowledge in Maya topics was not significantly correlated with the number of questions answered correctly for the Maya knowledge questions, r=-.077, p=.315. This suggests that there is not a significant relationship between participants' reported levels of interest and knowledge in Maya culture and their actual scores on the Maya knowledge questions. An independent samples t-test indicated the differences in mean between English language and Spanish language viewers was not significant (t(177)=-.223, p= .824.).

Table 2.5: Maya knowledge and astronomy knowledge, mean and standard deviation

	Total (N=179)		English Film (N=156)		Spanish Film (N=23)		P Value
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	
Maya Knowledge Items Correct	2.79	1.21	2.79	1.23	2.86	1.10	.824
Astronomy Knowledge Items Correct	2.13	1.35	2.28	1.35	1.17	0.94	.000

Note: Total Maximum Points Possible is five per measurement

Astronomy Knowledge Questions

Overall, participants earned less than half (42.6%) of the points possible for the astronomy knowledge questions. English language viewers of the show had a higher mean than Spanish language viewers of the show for the number of astronomy knowledge questions answered correctly. Viewers of the Spanish language version of the show had a lower standard deviation than viewers of the English language version of the show. An independent samples t-test indicated the difference between English language and Spanish language viewers was significant (t(177)= 5.00, p=.000). Our results suggest English language viewers had significantly higher knowledge of astronomy than Spanish language viewers.

Data suggest there are differences between Spanish language and English language viewers in a number of the variables measured as independent variables. Spanish language viewers self-reported significantly higher interest and knowledge in Maya culture than English language viewers. Although not significant, English language viewers reported a slightly higher level of connection to Maya culture. English language viewers reported a significantly higher connection to astronomy than Spanish language viewers. There was very little difference in the knowledge of Maya questions answered correctly between the two groups. English language viewers answered a significantly higher number of the astronomy knowledge questions correctly.

Question 2: Are there differences, based on the language of the show, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Perception of the overall show

Both groups were clearly positive in their perceptions of the show (Table 2.6). Spanish language viewers of the show had much higher positive perceptions (17.19/18) of the show than English language viewers (11.77/18), and a much lower standard deviation than English language viewers of the show. Spanish language viewers had a much lower score (0.10/18) than English language viewers (1.08/18) on negative perceptions of the show with lower standard deviations. The "net" scores, the positive mean score minus the negative mean score, reveal the distances between positive perceptions of the show. Spanish language viewers had a 17.09 positive net score or 94.9% of potential positive score. English language viewers had a 10.69 positive net score or 59.4% of potential positive score. Spanish language viewers had much higher positive net scores than English language viewers. Overall, results suggest both groups were extremely positive and not very negative in their overall perceptions of the show.

An independent t-test indicated significant differences between groups on the positive perceptions of the show semantic differential scale, (t(170)= -5.41, p=.000). Spanish language viewers had significantly higher positive scores. An independent t-test indicated significant differences between groups on the negative perceptions of the show semantic differential scale, (t(170)= 2.17, p=.000). Those who viewed the English language version of the show had significantly higher negative scores (Table 2.6).

Table 2.6: Positive and negative perceptions of the show, mean and standard deviation by film viewed

	Total (N=172)		English Film (N=151)		Spanish Film (N=21)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the show	12.44	4.64	11.77	4.54	17.19	1.43	.000
Negative perceptions of the show	0.96	1.97	1.08	2.07	0.10	0.30	.000

Perception of visuals

Mean scores and standard deviations on perceptions of visuals were parallel to the overall perceptions of the show (Table 2.7). Spanish language viewers had both a higher mean on positive and a lower mean on negative than English language viewers (15.29 and 1.62 versus 11.44 and 1.79). The net mean scores were also in a similar order with Spanish language having a net positive score of 13.67 (75.94%) and English language having a net positive score of 9.65 (53.61%).

An independent t-test indicated significant differences between groups on the positive perceptions of the visuals semantic differential scale, (t(169)= -4.31, p=.000). Shown below (Table 2.7), viewers of the Spanish language version of the show had significantly higher positive perceptions of the visuals compared to viewers of the English language version of the show. An independent t-test did not indicate significant differences between groups on the negative perceptions of the show semantic differential scale, (t(169)= 0.38, p=.707). Viewers of the English language version of the show had a higher mean and standard deviation than viewers of the Spanish language version of the show, for the negative perceptions of the visuals semantic differential scale.

Table 2.7: Positive and negative perceptions of the visuals, mean and standard deviation by film viewed

	Total (N=171)		English Film (N=150)		Spanish Film (N=21)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the visuals	11.91	4.02	11.44	4.04	15.29	1.42	.000
Negative perceptions of the visuals	1.77	1.90	1.79	1.96	1.62	1.43	.707

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

Between the two groups, Spanish language viewers had significantly higher positive scores for both perceptions of the overall show and perceptions of the visuals. This suggests that the show in Spanish, for those who chose this version, had an influence on their perceptions of the show and its visuals. These viewers had higher, positive perceptions of the show and its visuals.

What did they like about the show?

Overall, participants rated each item asking them what they liked about the show above 5.20 (Table 2.8), suggesting that participants had moderately positive levels of how much they liked each of these components of the show. Spanish language viewers had means that were higher and standard deviations that were much lower than English language viewers for each of these items. The extremely low standard deviations suggest a unified response between six and seven for most of the Spanish language viewers. There were differences between groups in the rank order of the items as well, with Spanish language viewers rating *A story about the Maya and their culture including their knowledge and use of astronomy* as the highest item, while English language viewers rated *A story about astronomical concepts and how the Maya learned these concepts* as the highest item. The finding might suggest the source of variance in terms of relationship to the cultural wrapper.

Table 2.8: What did participants like about the show, mean and standard deviation by show viewed

	Order		English Film (N=155)		Spanish Film (N=22)		P Value
	Eng	Sp	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya and their culture including their knowledge and use of astronomy	2	1	5.73	1.29	6.91	0.43	.000
A story about astronomical concepts and how the Maya learned these concepts	1	2	5.85	1.17	6.77	0.53	.000
A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society	3	3	5.23	1.55	6.59	0.73	.001
A story of Maya folklore and mythology and how that relates to Maya culture	3	4	5.23	1.55	6.59	0.73	.000

Notes: Descriptions shown in rank order by Spanish language viewer rating; items were rated on a seven point scale

Independent samples t-tests were run for each of the items in Table 2.8. Spanish language viewers had significantly higher means for each of the four items: *A story about the Maya and their culture including their knowledge and use of astronomy,* ($t(174)= -8.56$, p=.000); *A story about astronomical concepts and how the Maya learned these concepts,* ($t(175)= -6.31$, p=.000); *A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society,* ($t(175)= -3.30$, p=.001); *A story of Maya folklore and mythology and how that relates to Maya culture,* ($t(175) -6.79$, p=.000). Spanish

language viewers had significantly higher means than English language viewers for each item. Results suggest that Spanish language viewers liked each of the aspects of the show measured by these items at statistically significantly higher levels than English language viewers.

Data informing question two suggest that there are significant differences, based on the language of the show, in viewer perceptions of the show, perceptions of the visuals, and what they liked about the show. Spanish language viewers reported significantly higher positive perceptions of the show over English language viewers. Spanish language viewers reported significantly higher positive perceptions of the visuals over English language viewers. Spanish language viewers had significantly higher means for each of the four items asking what they liked about the show.

Question 3: Are there differences, based on the language the show was viewed in, in viewer learning?

What did the movie communicate?

Both English language and Spanish language viewers rated each of the eight items asking what the film communicated as very positive, with six of the items being rated above 6.0 (on a 7-point scale) by the English language group and all eight items being rated above 6.0 by the Spanish language group. Spanish language viewers rated each item higher than English language viewers. Standard deviations were mixed with English language viewers being lower on five of the eight items. There were differences in the rank order of these items between groups. Spanish language viewers rated *The night sky represents the origin story of the Maya* as their highest rated item, while this was the sixth highest rated item by English language viewers. English language viewers rated *Corn was so important to the Maya that it played a strong role in origin stories* as the highest concept communicated by the film, while Spanish language viewers rated this third.

Independent samples t-tests were run for each of the items in Table 2.9. Spanish language viewers had significantly higher means for items: *The night sky represents the origin story of the Maya* ($t(175)= -3.67$, p=.000); *Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into the Maya culture, religion, and agriculture* ($t(174)= -2.58$, p=.011); *Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy,* ($t(174)= -2.98$, p=.003); *Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life*, ($t(174)= -2.40$, p=.018). Table 2.9 shows the findings which suggest that Spanish language viewers felt the show was more effective at communicating each of the concepts measured than did English language viewers.

Table 2.9: What did the film communicate, mean and standard deviation by film viewed

	Order		English Film (N=154)		Spanish Film (N=23)		P Value
	Eng	Sp	$\bar{x}$	SD	$\bar{x}$		
The night sky represents the origin story of the Maya.	6	1	6.01	1.14	6.91	0.29	.000
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	5	2	6.06	1.02	6.68	1.29	.011
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	2	3	6.52	0.81	6.65	1.30	.495
Corn was so important to the Maya that it played a strong role in origin stories.	1	3	6.55	0.89	6.65	1.27	.615
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	8	5	5.95	1.04	6.64	0.66	.003
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	3	5	6.35	0.83	6.64	1.29	.164
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	7	7	5.96	1.16	6.57	0.84	.018
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	4	8	6.25	1.21	6.30	1.72	.841

Note: Items rated on a seven point scale, are shown in rank order by Spanish viewer mean

Primary story communicated by the show

Participants were asked to assign points to each of four descriptions with a maximum of 100 points total between the four descriptions (as shown in Table 2.10). English language viewers rated the item *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* as the highest, Spanish language viewers rated this as second highest. Spanish language viewers rated *A story about the Maya and their culture, including their knowledge and use of astronomy* as the highest; English language viewers rated this second highest.

Independent samples t-tests were run for each of the descriptions. English language viewers rated *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* significantly higher than Spanish language viewers ($t(174)= 1.64$, p=.030). Those who viewed the English language version of the film rated that description significantly higher than Spanish language film viewers (Table 2.10).

Table 2.10: How much the show told a story, mean and standard deviation by film viewed

	Order		English Film (N=154)		Spanish Film (N=23)		P Value
	Eng	Sp	$\bar{x}$				
A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society	1	2	27.77	8.95	24.55	5.75	.030
A story about the Maya and their culture, including their knowledge and use of astronomy	2	1	25.28	8.38	27.50	7.52	.240
A story of Maya folklore and mythology and how that relates to Maya culture	3	2	24.28	9.14	24.54	3.75	.807
A story about astronomical concepts and how the Maya learned these concepts	4	4	21.81	9.04	23.41	4..73	.206

Notes: Descriptions shown in rank order by English language viewer rating with maximum possible points 100, minimum possible points zero

Data informing question three suggest that there are differences, based on the language of the show, on viewer learning. As measured by what participants felt the show communicated, Spanish language viewers rated each item higher than English language viewers, with four items being rated significantly higher. English language viewers stated the show told *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* significantly higher than Spanish language viewers who rated *A story about the Maya and their culture, including their knowledge and use of astronomy* as the highest item the story told.

Question 4: Are there differences, based on connection to Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Participants were divided into three categories based on their summative mean on the pre-measurement of connection to Mayan culture. The three cut points, as determined by SPSS, in which three near equal groups were created, were "low connection" (n=61, $\bar{x}$ =3.75 or below), "medium connection" (n=64, $\bar{x}$ =3.76 to 5.00) and "high connection" (n=51, $\bar{x}$ =5.01 and above). The groups are not exactly even due to a number of cases falling exactly on the cut points. These cases were assigned to the category below the cut point.

Perceptions of the overall show

Each of the three levels of connection to Mayan culture groups had high positive perceptions of the overall show and low negative perceptions of the show (Table 2.11). The High Connection group had the highest positive perceptions at 13.87/18 and the lowest negative perceptions at 0.70/18. This was followed by the Medium Connection group (12.83/18 and 0.74/18) and then the Low Connection group (11.00/18 and 1.33/18). The High Connection group had a positive net score of 13.17 or 73.17% of potential positive score. The Medium Connection group had a positive net score of 12.09 or 67.17% of potential positive score. The Low Connection group had a positive net score of 9.67 or 53.72% of potential positive score.

A MANOVA was run with connection level as the independent variable and positive and negative perceptions of the show as the dependent variables. The results indicated statistically significant

differences between groups on the positive perceptions of the show semantic differential scale, (F(2, 161)= 5.645, p=.004, η^2 =.065). Post-hoc analysis (Bonferonni) indicated that those in with High Connection had significantly higher scores than those with Low Connection. Connection level did not have a significant effect on negative perceptions of the show.

Table 2.11: Positive and negative perceptions of the show, mean and standard deviation by level of connection

	High (N=46)		Medium (N=58)		Low (n=60)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the show	13.87	4.50	12.83	3.97	11.00	4.93	.004
Negative perceptions of the show	0.70	2.34	0.74	1.33	1.33	2.06	.148

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

Perceptions of visuals

Each of the three groups had high levels of positive perceptions of the overall show and low levels of negative perceptions of the visuals (Table 2.12). The High Connection group had the highest positive perceptions of the visuals (13.06/18). However, the High Connection group also had the highest level of negative perceptions of the visuals (1.91/18). The Medium Connection group had the second highest positive perceptions of the visuals and the lowest level of negative perceptions of the visuals (12.14/18 and 1.48/18). The Low Connection group had the lowest level of positive perceptions of the visuals and second lowest negative perceptions of the visuals (10.88/18 and 1.86/18). The High Connection group had a positive net score of 11.15 or 61.94% of potential positive score. The Medium Connection group had a positive net score of 10.66 or 59.02 of potential positive score. The Low Connection group had a positive net score of 9.02 or 50.11% of potential positive score.

A MANOVA was run with Connection level as the independent variable and positive and negative perceptions of the visuals entered as the dependent variables. The results indicated connection had significant differences between groups on positive perceptions of the visuals (F(2, 161)= 4.07, p=.019, η^2 =.048). Post-hoc analysis indicated that those in the High Connection group had significantly higher scores than those with Low Connection scores. Connection level did not have significant differences between groups on negative perceptions of the show (Table 2.12). These results suggest that connection did influence participants' positive perceptions of the visuals.

Table 2.12: Perceptions of visuals, mean and standard deviation by level of connection

	High (N=46)		Medium (N=58)		Low (N=60)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the visuals	13.06	4.06	12.14	3.21	10.88	4.51	.019
Negative perceptions of the visuals	1.91	2.80	1.48	1.33	1.86	1.44	.426

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

What did they like about the show?

Each of the three groups gave positive scores to the four items asking what viewers liked about the show (Table 2.13). The High Connection group rated each item higher than the Medium and Low Connection groups. Standard deviations were mixed between the groups. The Medium Connection group rated each item higher than the Low Connection group.

A MANOVA was run with level of Connection as the independent variable and the four items regarding what viewers liked about the show as the dependent variable. Results indicated Connection level had significant differences between groups for the item: *A story of Maya folklore and mythology and how that relates to Maya culture,* ($F(2,165)= 14.80$, p=.002, $\eta^2 =.072$). Post-hoc analysis indicated that those in with High Connection had significantly higher scores than those with Low Connection (Table 2.13). These data suggest that the higher a viewer's level of Connection the move he/she liked each measured aspect of the show.

Table 2.13: What did they like about the show, mean and standard deviation by level of connection

	High (N=47)		Medium (N=62)		Low (N=59)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya and their culture including their knowledge and use of astronomy	6.15	1.23	5.94	1.16	5.61	1.41	.091
A story about astronomical concepts and how the Maya learned these concepts	6.17	1.17	6.02	1.11	5.78	1.20	.217
A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society	6.17	1.24	5.94	1.08	5.75	1.15	.173
A story of Maya folklore and mythology and how that relates to Maya culture	5.91	1.46	5.47	1.48	4.86	1.60	.002

Notes: Descriptions shown in rank order by Spanish language viewer rating with rating on a seven point scale

Question 5: Are there differences, based on connection to Mayan culture, in viewer learning?

What did the movie communicate?

All groups gave moderate to highly positive scores for each of the items asking what the show communicated (Table 2.14). The High Connection group had higher means for each item than the Low Connection group. Standard deviations were mixed between the High and Low Connection groups. The High Connection group had higher means for each item than the Medium Connection group, with the exception of *Corn was so important to the Maya that it played a strong role in origin stories*. The Medium Connection group had higher means and lower standard deviations for each item than the Low Connection group. The Medium Connection group had lower standard deviations than the High Connection group with the exception of two of the items.

A MANOVA was run with Connection level as the independent variable and the items on what the show communicated as the dependent variables. Results indicated there were significant differences between Connection groups for the item*: Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture* ($F(2,162)= 3.41$, p=.036 $\eta^2 =.032$). Post-hoc analysis indicated those in the High Connection group had significantly higher scores than those in the Low Connection group. These results suggest that those who had high levels of Connection felt the show was better at communicating the items measured (Table 2.14).

Table 2.14: What did the show communicate, mean and standard deviation by level of connection

	High (N=46)		Medium (N=58)		Low (N=60)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	6.70	0.87	6.60	0.67	6.49	0.77	.396
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	6.59	0.80	6.47	0.77	6.24	0.80	.069
Corn was so important to the Maya that it played a strong role in origin stories.	6.59	1.05	6.60	0.69	6.56	0.88	.967
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	6.54	1.00	6.28	1.29	6.03	1.35	.116
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	6.48	1.05	6.10	0.93	5.98	1.01	.036
The night sky represents the origin story of the Maya.	6.30	1.01	6.12	0.92	5.97	1.34	.304
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	6.26	1.10	6.08	1.12	5.86	1.15	.200
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	6.23	1.09	6.05	0.87	5.88	1.12	.252

Notes: Items rated on a seven-point scale are shown in rank order by High Connection mean

Primary story communicated by the show

Participants in the Low Connection group had *A story about the Maya and their culture, including their knowledge and use of astronomy* the highest mean number of points attributed. This was ranked second by those with High Connection and third by those with Medium Connection. Those in the Medium and High Connection groups gave *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* the highest mean. This was ranked second by those with Low Connection.

A MANOVA was run with level of connection as the independent variable and the items measuring how much the show told each story as the dependent variables. Results suggested that differences between groups were not significant for any of the items (Table 2.15).

Table 2.154: How much the show told a story, mean and standard deviation by connection

	High (N=47)		Medium (N=61)		Low (N=59)		P Value
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	
A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society	26.96	8.04	28.13	7.79	26.49	9.80	.565
A story about the Maya and their culture, including their knowledge and use of astronomy	26.64	7.78	24.50	7.65	26.92	8.27	.250
A story of Maya folklore and mythology and how that relates to Maya culture	23.15	8.84	25.46	9.74	24.12	7.44	.386
A story about astronomical concepts and how the Maya learned these concepts	23.62	9.01	20.93	9.71	21.92	6.81	.272

Notes: Descriptions shown in rank order by High Connection mean; Maximum possible points was 100, minimum possible points was zero

Question 6: Are there differences, based on prior knowledge of astronomy, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Participants were divided into three categories based on their summative mean on the pre-measurement of prior knowledge of astronomy. The three cut points, as determined using SPSS, in which three near equal groups were created, were "low astronomy knowledge" (n=66, $\bar{X}$ =1.00 or below), "medium astronomy knowledge" (n=88, $\bar{X}$ = 1.01 to 3.00) and "high astronomy knowledge" (n=31, $\bar{X}$ =3.01 and above). The groups are not even due to cases falling exactly on the cut points. These cases were assigned to the category below the cut point. The N for these analyses is different from the total N due to cases with missing data.

Perceptions of the overall show

Each of the three prior knowledge of astronomy groups had high positive perceptions of the show and low negative perceptions of the show (Table 2.16). The Low prior knowledge of astronomy group had the highest perceptions of the show (14.36/18), followed by the Medium prior knowledge of astronomy group (11.64/18), and then the High prior knowledge of astronomy group (10.87/18). The High prior knowledge of astronomy group had the lowest standard deviation, followed by the Low prior knowledge of astronomy group, and the Medium prior knowledge of astronomy group. The Low prior knowledge of astronomy group had the lowest negative perceptions of the show (0.61/18), followed by the High prior knowledge of astronomy group (0.73/18) and then the Medium prior knowledge of astronomy group (1.29/18). The Low prior knowledge of astronomy group had the lowest standard deviation, followed by the High prior knowledge of astronomy group and the Medium prior knowledge of astronomy group. The Low prior knowledge of astronomy group had a positive net score of 13.75 or 76.39% of potential positive score. The Medium prior knowledge of astronomy group had a positive net score of 10.35 or 57.50% of potential positive score. The High prior knowledge of astronomy group had a positive net score of 10.14 or 56.33% of potential positive score.

A MANOVA was run with prior knowledge of astronomy level entered as the independent variable and perceptions of the visuals as the dependent variables. The results indicated prior knowledge of astronomy had significant differences between groups on the positive perceptions of the show semantic differential scale, (F(2, 169)= 8.72, p=.000, η^2 =.094). Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with High and Medium prior

knowledge of astronomy. The difference between Medium and High prior knowledge of astronomy was not significant (Table 2.16). These results suggest that those with higher levels of prior knowledge of astronomy had lower positive perceptions of the show.

Table 2.16: Positive and negative perceptions of the show, mean and standard deviation by prior knowledge of astronomy level

	High (N=59)		Medium (N=83)		Low (N=30)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the show	10.87	3.97	11.64	4.79	14.36	4.13	.000
Negative perceptions of the show	0.73	1.53	1.29	2.38	0.61	1.41	.102

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

Perceptions of visuals

Each of the three prior knowledge of astronomy groups had high positive perceptions of the visuals and low negative perceptions of the show. The Low prior knowledge of astronomy group had the highest perceptions of the visuals (13.22/18), followed by the Medium prior knowledge of astronomy group (11.51/18), and then the High prior knowledge of astronomy group (10.43/18). The Low prior knowledge of astronomy group had the lowest negative perceptions of the show (1.58/18), followed by the High prior knowledge of astronomy group (1.77/18) and then the Medium prior knowledge of astronomy group (1.90/18). The Low prior knowledge of astronomy group had a positive net score of 13.75 or 76.39% of potential positive score. The Medium prior knowledge of astronomy group had a positive net score of 10.35 or 57.50% of potential positive score. The High prior knowledge of astronomy group had a positive net score of 10.14 or 56.33% of potential positive score.

Table 2.17: Positive and negative perceptions of the visuals, mean and standard deviation by prior knowledge of astronomy level

	High (n=59)		Medium (n=82)		Low (n=30)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the visuals	10.43	3.95	11.51	4.04	13.22	3.70	.003
Negative perceptions of the visuals	1.77	1.61	1.90	2.27	1.58	1.43	.607

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

A MANOVA was run with prior knowledge of astronomy level entered as the independent variable and perceptions of the visuals as the dependent variables. The results indicated prior knowledge of astronomy had significant differences between groups for positive perceptions of the visuals ($F(2, 168)= 5.87$, $p=.003$, $\eta^2=.065$). Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with High and Medium prior knowledge of astronomy. The differences between Medium and High prior knowledge of astronomy were not significant. These results suggest that the group with Low prior knowledge of astronomy had higher positive perceptions of the visuals than those in the High prior knowledge of astronomy group (Table 2.17).

What did they like about the show?

Each of the three prior knowledge of astronomy groups gave positive ratings to the four items asking what they liked about the show. The Low prior knowledge of astronomy group strongly agreed with

three of the items and rated them above six. The Low prior knowledge of astronomy group had the highest rating and lowest standard deviation for each of the items. The Medium prior knowledge of astronomy group was higher than the High prior knowledge of astronomy group for each item with the exception of *A story about astronomical concepts and how the Maya learned these concepts.*" The Low prior knowledge of astronomy group rated *A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society* as the highest item they liked about the show. The Medium and High prior knowledge of astronomy groups rated *A story about astronomical concepts and how the Maya learned these concepts* as the highest item they liked about the show.

A MANOVA was run with prior knowledge of astronomy level entered as the independent variable and the four items asking what viewers liked about the show as dependent variables. Results indicated a statistically significant difference between prior knowledge of astronomy groups for each of the four items entered. Prior knowledge of astronomy had significant differences between groups for the item *A story about the Maya and their culture including their knowledge and use of astronomy*, ($F(2,173)= 5.92$, $p=.003$, $\eta^2=.064$). Prior knowledge of astronomy had significant differences between groups for the item: *A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society*, *(*$F(2,173)= 9.26$, $p= .000$, $\eta^2 = .097$). Prior knowledge of Astronomy had significant differences between groups for the item: *A story about astronomical concepts and how the Maya learned these concepts,* ($F(2,173)= 4.16$, $p= .017$, $\eta^2 = .046$) prior knowledge of astronomy had significant differences between groups for the item: *A story of Maya folklore and mythology and how that relates to Maya culture,"*($F(2,173)= 8.36$, $p=.000$, $\eta^2=.088$). Post-hoc analysis indicated that those with Low prior knowledge of astronomy had significantly higher means for each of these items than did those with Medium and High prior knowledge of astronomy. These data suggest that those with low prior knowledge of astronomy liked the measured aspects of the show significantly higher than those with higher levels of prior knowledge of astronomy.

Table 2.18: What did they like about the show, mean and standard deviation by prior knowledge of astronomy level

	High (N=63)		Medium (N=84)		Low (N=29)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society	5.60	1.10	5.70	1.25	6.42	0.86	.000
A story about the Maya and their culture including their knowledge and use of astronomy	5.53	1.28	5.68	1.39	6.30	0.98	.003
A story about astronomical concepts and how the Maya learned these concepts	5.93	1.23	5.73	1.26	6.27	0.87	.017
A story of Maya folklore and mythology and how that relates to Maya culture	4.70	1.60	5.24	1.59	5.97	1.27	.000

Notes: Descriptions rated on a seven point scale, shown in rank order Low prior knowledge of astronomy rating

Question 7: Are there differences, based on prior knowledge of astronomy, in viewer learning?

What did the movie communicate?

Each of the three prior knowledge of astronomy groups rated the items asking what the film communicated moderately to highly positive (Table 2.19). The Low prior knowledge of astronomy group had the highest means for each of these items and the lowest standard deviation for six of the eight items. Both High and Low prior knowledge of astronomy groups rated *Corn was so important to the Maya that it played a strong role in origin stories* as the highest item communicated by the movie. This was rated second by the Medium prior knowledge of astronomy group. The Medium prior knowledge of astronomy group rated *By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons* as the highest item communicated by the movie. This was rated second by both the High and Low prior knowledge of astronomy groups.

A MANOVA was run with prior knowledge of astronomy level entered as the independent variable and the eight items on what the movie communicated as the dependent variable. Prior knowledge of astronomy had significant differences between groups for four of the items measuring topics the film communicated. There were significant differences between groups for the item:

Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy" ($F(2,170)= 6.22$, $p=.002$ $\eta^2=.068$.) Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with High and Medium prior knowledge of astronomy.

Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture,($F(2,170)= 3.28$, $p=.040$ $\eta^2=.037$.) Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with Medium prior knowledge of astronomy.

Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life" ($F(2,170)= 9.45$, $p=.000$ $\eta^2=.100$.) Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with High and Medium prior knowledge of astronomy.

The night sky represents the origin story of the Maya" ($F(2,170)= 4.87$, $p=.009$ $\eta^2=.054$.) Post-hoc analysis indicated that those in with Low prior knowledge of astronomy had significantly higher scores than those with Medium prior knowledge of astronomy. These data suggest that those with Low prior knowledge of astronomy consistently rated the items on what the show communicated higher than those with High and Medium prior knowledge of astronomy.

Table 2.19: What did the show communicate, mean and standard deviation by prior knowledge of astronomy level

	High (N=59)		Medium (N=84)		Low (N=30)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Corn was so important to the Maya that it played a strong role in origin stories.	6.57	0.82	6.46	1.00	6.76	0.60	.121
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	6.53	0.78	6.48	0.90	6.73	0.55	.002
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	6.30	0.99	6.15	1.34	6.73	1.18	.393
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	6.43	0.77	6.29	0.91	6.58	0.62	.104
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	5.93	1.01	5.75	1.28	6.54	0.77	.000
The night sky represents the origin story of the Maya.	5.90	1.32	5.94	1.12	6.47	0.90	.009
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	5.83	0.95	5.85	1.10	6.41	0.85	.002
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	6.23	0.86	5.96	1.11	6.39	0.87	.040

Notes: Items, rated on a seven-point scale, are shown in rank order by Low prior knowledge of astronomy mean

Primary story communicated by the show

All three prior knowledge of astronomy groups rated *A story about the Maya and their culture, including their knowledge and use of astronomy* as the highest story the show told (Table 2.20). Those in the medium and low prior knowledge of astronomy categories rated *A story about astronomical concepts and how the Maya learned these concepts* with the lowest mean; those in the high prior knowledge of astronomy category rated *A story of Maya folklore and mythology and how that relates to Maya culture* the lowest.

A MANOVA was run with prior knowledge of astronomy level entered as the independent variable and the four items asking how much the show told a story as the dependent variables. The results suggested no significant differences in mean based on prior knowledge of astronomy level. These data suggest consistency across groups for how much viewers felt the show told each story.

Table 2.20: How much the show told a story, mean and standard deviation by prior knowledge of astronomy level

	High (N=63)		Medium (N=84)		Low (N=29)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society	26.96	8.04	28.13	7.79	26.49	9.80	.565
A story about the Maya and their culture, including their knowledge and use of astronomy	26.64	7.78	24.50	7.65	26.92	8.27	.250
A story of Maya folklore and mythology and how that relates to Maya culture	23.15	8.84	25.46	9.74	24.12	7.44	.386
A story about astronomical concepts and how the Maya learned these concepts	23.62	9.01	20.93	9.71	21.92	6.81	.272

Notes: Descriptions shown in rank order by the Low prior knowledge of astronomy rating; maximum possible points was 100, minimum possible points was zero

Question 8: Are there differences, based on interest in Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Overall perceptions of the show

Participants were divided into three categories based on their summated mean on the pre measurement of interest in Mayan culture. The three cut points, as determined by SPSS, in which three near equal groups were created, were "low Maya interest" (N=79, $\bar{x}$ =5.00 or below), "medium Maya interest" (N=48, $\bar{x}$ = 5.01 to 6.00) and "high Maya interest" (N=49, $\bar{x}$ =6.01 and above). The groups are not even due to cases falling exactly on the cut points. These cases were assigned to the category below the cut point.

A MANOVA indicated interest in Mayan culture had a significant effect on the positive perceptions of the show semantic differential scale (F(2, 161)= 23.20, p=.000, η^2 =.224). High levels of prior knowledge of astronomy had an additive effect on these scores. Post-hoc analysis indicated that those in the High interest group had significantly higher scores than those in the medium and low interest groups. Interest in Mayan culture had a significant effect on the positive perceptions of the show semantic differential scale (F(2, 161)= 3.52, p=.032, η^2 =.042). High levels of interest had a reducing effect on these scores. Post-hoc analysis indicated that those with high interest had significantly lower scores than those with low interest. Interest level did not have a significant effect on the difference between medium and low interest and medium and high interest (Table 2.21).

Table 2.21: Positive and negative perceptions of the show, mean and standard deviation by level of interest in Mayan culture

	High (n=45)		Medium (n=44)		Low (n=75)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the show	15.22	4.61	13.48	4.31	10.19	4.33	.000
Negative perceptions of the show	0.53	1.29	0.64	1.14	1.37	2.48	.032

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

Perception of visuals

Positive perceptions of the visuals were good, entertaining, informative, comprehensible, supported the story, and complex. Negative perceptions of the visuals were bad, boring, not informative, incomprehensible, distracted from the story, and simple.

A MANOVA indicated interest in Mayan culture had a significant effect on positive perceptions of the visuals ($F(2, 164)= 15.07$, p=.000, $\eta^2 =.158$). Post-hoc analysis indicated that those in the High interest group had significantly higher scores than those in the Low interest group. Those with Medium interest had significantly higher scores than those with Low interest. The difference between High and Medium positive scores was not statistically significant. Interest in Mayan culture did not have a significant effect on the negative perceptions of the visuals (Table 2.22).

Table 2.22: Positive and negative perceptions of the visuals, mean and standard deviation by level of interest in Mayan culture

	High (N=45)		Medium (N=44)		Low (N=75)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Positive perceptions of the visuals	14.28	2.64	12.05	4.07	10.45	4.07	.000
Negative perceptions of the visuals	1.59	1.34	1.77	1.34	1.82	2.42	.798

Note: Maximum possible amount of points per scale was 18, minimum possible amount of points per scale was zero

What did they like about the show?

Interest in Mayan culture had a significant effect for each item shown in Table 2.23.

A story about the Maya and their culture including their knowledge and use of astronomy ($F(2,165)= 25.03$, p=.000, $\eta^2 =.233$). Post-hoc analysis (Bonferonni) indicated that those in with high and medium interest had significantly higher scores than those with low interest.

A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society ($F(2,165)= 16.50$, p= .000, $\eta^2 = .167$). Post-hoc analysis indicated that those in with high and medium IONNECTION had significantly higher scores than those with low interest.

A story about astronomical concepts and how the Maya learned these concepts ($F(2,165)= 9.20$, p= .000, $\eta^2 = .100$). Post-hoc analysis indicated that those in with high and medium interest had significantly higher scores than those with low interest.

A story of Maya folklore and mythology and how that relates to Maya culture ($F(2,165)= 15.79$, p=.000, $\eta^2 =.161$). Post-hoc analysis indicated that those in with high and medium interest had significantly higher scores than those with low interest.

Table 2.23: What did they like about the show, mean and standard deviation by level of interest in Mayan culture

	High (N=48)		Medium (N=46)		Low (N=74)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya and their culture including their knowledge and use of astronomy	6.65	0.67	6.15	1.03	5.22	1.40	.000
A story about astronomical concepts and how the Maya learned these concepts.	6.38	1.00	6.22	1.01	5.57	1.41	.000
A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society	6.56	0.65	6.07	1.02	5.45	1.28	.000
A story of Maya folklore and mythology and how that relates to Maya culture	6.21	1.20	5.57	1.41	4.73	1.60	.000

Notes: Descriptions were rated on a seven-point scale and are shown in rank order by high interest in Mayan culture rating

Question 9: Are there differences, based on interest in Mayan culture, in viewer learning?

What did the movie communicate?

Interest in Mayan culture had a significant effect on each of the items measuring topics the film communicated. Interest in Mayan culture had a significant effect on:

By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons ($F(2,162)= 5.93$, $p=.003$ $\eta^2=.068$). Post-hoc analysis for this item indicated that those in the high interest had significantly higher scores than those in the low interest.

Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings ($F(2,162)= 14.50$, $p=.000$ $\eta^2=.152$). Post-hoc analysis for this item indicated that those in the high and medium interest had significantly higher scores than those in the low interest.

Corn was so important to the Maya that it played a strong role in origin stories ($F(2,162)= 5.55$, $p=.005$ $\eta^2=.064$). Post-hoc analysis for this item indicated that those in the high interest k had significantly higher scores than those in the low interest.

By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture ($F(2,162)= 4.66$, $p=.011$ $\eta^2=.054$). Post-hoc analysis for this item indicated that those in the high interest had significantly higher scores than those in the low interest.

Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture ($F(2,162)= 8.23$, $p=.000$ $\eta^2=.092$). Post-hoc analysis for this item indicated that those in the high interest had significantly higher scores than those in the low interest.

The night sky represents the origin story of the Maya ($F(2,162)= 11.04$, $p=.000$ $\eta^2=.120$). Post-hoc analysis for this item indicated that those in the high and medium interest had significantly higher

scores than those in the low interest. Those with high interest had significantly higher scores than those with medium interest.

Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life ($F(2,162)= 15.83$, p=.000 $\eta^2 =.163$. Post-hoc analysis for this item indicated that those in the high and medium interest had significantly higher scores than those with low interest. Those with high interest had significantly higher scores than those with medium interest.

Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy ($F(2,162)= 7.49$, p=.001 $\eta^2 =.085$). Post-hoc analysis for this item indicated that those in with high and medium interest had significantly higher scores than those with low interest.

Table 2.24: What did the movie communicate, mean and standard deviation by level of interest in Mayan culture

	High (N=45)		Medium (N=46)		Low (N=74)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Corn was so important to the Maya that it played a strong role in origin stories.	6.89	0.38	6.63	0.64	6.36	1.11	.005
By observing the patterns of the sun, moon, and planets, the Maya created a precise, accurate calendar that marked the seasons.	6.84	0.42	6.67	0.63	6.38	0.93	.003
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	6.82	0.39	6.54	0.66	6.09	0.92	.000
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	6.71	0.66	6.13	0.91	5.61	1.28	.000
The night sky represents the origin story of the Maya.	6.69	0.63	6.13	1.13	5.76	1.19	.000
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	6.58	0.66	6.26	0.83	5.85	1.17	.000
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	6.49	121	6.57	0.77	5.95	1.43	.011
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	6.40	0.81	6.20	0.88	5.72	1.14	.011

Notes: Items were rated on a seven-point scale and are shown in rank order by high interest in Mayan culture mean

Primary story communicated by the show

Interest in Mayan culture did not have a significant effect for any of the four descriptions of the story the movie told. Participants in all three interest categories had *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* as the highest mean (Table 2.25). All three interest categories also rated *A story about astronomical concepts and how the Maya learned these concepts* with the lowest mean.

Table 2.25: How much the show told a story, mean and standard deviation by level of interest in Mayan culture

	High (N=73)		Medium (N=46)		Low (N=48)		P Value
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society	26.23	5.17	27.59	9.94	27.64	9.51	.641
A story about the Maya and their culture, including their knowledge and use of astronomy	26.21	6.51	26.00	9.58	25.11	7.70	.722
A story of Maya folklore and mythology and how that relates to Maya culture	24.33	8.43	23.30	8.53	24.99	9.09	.595
A story about astronomical concepts and how the Maya learned these concepts	21.77	8.84	22.67	9.52	21.80	7.90	.840

Notes: Descriptions shown in rank order by high interest in Mayan culture rating; maximum possible points was 100, minimum possible points was zero

Questions 10 – 17

By interest in astronomy

Participants were divided into three categories based on their summated mean on the post measurement of interest in astronomy. The three cut points, as determined by SPSS, in which three near equal groups were created, were "low interest in astronomy" (n=68, $\bar{x}$ =4.50 or below), "medium interest in astronomy" (n=55, $\bar{x}$ = 4.51 to 5.75) and "high interest in astronomy" (n=53, $\bar{x}$ =5.76 and above). The groups are not exactly even due to cases falling exactly on the cut points. These cases were assigned to the category below the cut point.

MANOVAs were run between groups for each of the items listed in the connection to Maya culture section above. Interest in astronomy had a significant effect between groups only for the item asking participants to rate how well they thought the film communicated: *Corn was so important to the Maya it played a strong role in origin stories* (F(2, 162)= 3.19, p= .044). Post-hoc analysis (Bonferonni) indicated that those in with Low interest in astronomy ($\bar{x}$ = 6.77, SD= 0.49) had significantly higher scores on this item than those with High interest ($\bar{x}$ = 6.36, SD= 1.17) in astronomy. The difference between the Low interest and Medium interest ($\bar{x}$ = 6.55, SD= 0.87) was not significant, the difference between High and Medium interest in astronomy was not significant.

By prior knowledge of Mayan Culture

Participants were divided into three categories based on their summated mean on the pre measurement of knowledge of Mayan culture. The three cut points, as determined by SPSS, in which three near equal groups were created, were "low Maya knowledge" (N=70, $\bar{x}$ =2.33 or below), "medium Maya knowledge" (N=62, $\bar{x}$ = 2.34 to 3.33) and "high Maya knowledge" (N=53, $\bar{x}$ =3.34 and above). The groups are not exactly even due to cases falling exactly on the cut points. These cases were assigned to the category below the cut point. MANOVAs were run between groups for each of the items listed in the connection to Mayan culture section. Prior knowledge of Mayan culture did not have a significant effect on any of the items measured. Spearman Rho analysis found prior knowledge of the Maya was not significantly correlated with any of the items measured.

By Age

Participants were split into three age groups, 18-29 (N=42), 30-49 (N=77), and 50 years old and above (N=62). MANOVAs were run for each of the items in the previous sections. There was one scale and one item in which age had a statistically significant effect on the mean. Age had a significant effect on positive perceptions of the show semantic differential scale ($F(2, 165)= 4.40$, p= .014, $\eta^2 = .051$). Post-hoc analysis indicated that those 50 years old and above ($\bar{x} = 13.87$, SD= 4.03) had significantly higher means for this scale than those age 18-29 ($\bar{x} = 11.12$, SD= 5.29). The 30-49 year old age group ($\bar{x} =$ 12.15, SD= 4.56) did not differ significantly from the two other groups. The item in which a MANOVA indicated statistically significant differences between age groups was from the what they liked about the show section on the item *A story about the Maya's knowledge of the science of astronomy and how this was important to Maya society* ($F(2, 169)= 4.10$, p= .018, $\eta^2 = .046$). Post-hoc analysis on this item indicated that those 50 years old and above ($\bar{x} = 6.30$, SD= 0.71) rated this item significantly higher than those age 18-29 years ($\bar{x} = 5.70$, SD= 1.36). Those age 30-49 ($\bar{x} = 5.84$, SD= 1.23) did not differ significantly from the other two groups.

By Sex

Independent samples t-tests were run between male and female participants for each of the items in the previous sections. There were two items that showed statistically significant differences between males and females. One item was from the section on what the film communicated: *Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture* ($t(163)= -2.06$, p=.041). Female participants ($\bar{x} =$ 6.33, SD= 1.00) had a higher mean than male participants ($\bar{x} = 6.01$, SD= 1.00).

The other statistically significant difference in mean between male and females was from the section what they liked about the show: *A story about astronomical concepts and how the Maya learned these concepts* ($t(164)= -2.11$, p= .037). Female participants ($\bar{x} = 6.15$, SD= 1.08) had a higher mean than male participants ($\bar{x} = 5.77$, SD= 1.24). The sex of the participants was not significantly correlated with any other item.

Discussion: Study 2

The concept of some type of cultural connection to the production does exist and does have an influence on learning and satisfaction. By constructing *Tales of the Maya Skies* with what we called a "cultural wrapper," in which the scientific messages, history messages, and narration are all wrapped together within a sub-cultural focus, it created a more positive response among those who viewed the Spanish-language production across all components of the study. The language of the show attended was the variable that showed the strongest influence in learning and satisfaction with the show overall. This finding is interesting given the very low correlation between expressed interest and prior knowledge (of astronomy and of Maya culture) across cultural sets.

The small number of those who viewed the production in Spanish, and the number of statistically significant items at the .05 level, indicates there is meaning in these data. It is highly likely that a larger population would maintain the mean differences between the cultural sets. Clearly, the connection was not necessarily "Mayan," as individuals did not identify their race/ethnicity within that category. The Spanish language very likely served as a bridge for shared heritage for those who engaged with the Spanish-language version.

Secondary influencers on learning and perceptions of the film were prior interest in and connection to Mayan culture. Those with high levels of prior interest and high levels of connection reported higher scores on most measures than did those with low levels of prior interest and low levels of connection.

The findings also showed that those who entered with higher knowledge of astronomy were uniformly less satisfied with the production and did not feel it strongly communicated its intended messages. Those with higher pre-existing knowledge of astronomy rated the show lower across the board, as it appears they "came for the astronomy" (an anecdotal statement made to one of the researchers; although there is no way of knowing if the individual making the statement had high or low prior knowledge of astronomy). It does suggest, again, the scientific components of the production may not be clearly delineated for visitors.

In summary, taking all analysis together, the viewer most likely to report very positive perceptions of the show and its visuals would have viewed the Spanish-language version of the show, had high levels of connection to Mayan culture, high levels of interest in Mayan culture, low levels of prior knowledge of astronomy, and been age 50 or older. Similarly, the viewers most likely to give the highest ratings of how well the show communicated each of eight items would have been Spanish language viewers with high connection to Mayan culture, high interest in Mayan culture, and low knowledge of astronomy. For both perceptions of the show and its messages communicated, viewer sex (male or female), interest in astronomy, and prior knowledge of Maya culture did not seem to have substantial impact.

For the items asking viewers what story the show told, our results suggest that no single story line was dominant. The perception of the storyline and main message provided is again an interesting finding, in that results regarding dominant messages were almost identical regardless of the cultural variable used to examine the data. No single narrative or message appeared to resonate as the big idea of the story for viewers. This could be a result of the cultural wrapper, in which mixing the cultural story, scientific story, mythological story, and sociological story did not result in a single clear narrative, but did weave those ideas together. The cultural wrapper was, perhaps, not defined enough to allow the clarity of the science to emerge as a clear and distinct component of the experience; if anything, the stories of Maya culture and mythology were more strongly taken away. It appears there is no dominant story, nor is there a hierarchy of stories which would provide the learning framework for messages across visitors.

Results: Study 3 – Physiological Effect of Immersion

Questions

The third portion of the Maya Skies research explored how the immersive experience, visual effects, and cultural narrative of *Tales of the Maya Skies* had impact on visitors' physiological, affective, and cognitive responses to the film. Within the full-dome environment at Chabot, researchers gathered viewers' physiologic response via heart rate and skin conductance, and continuous opinion rating of the show throughout viewing. These data allowed for triangulation of real-time physiologic and opinion data with the timeline of the show to provide insight into which aspects of the immersive experience and cultural narrative created the strongest response in visitors.

To answer these questions, three specific questions were articulated:

1) Which scenes of the film correspond to the highest and lowest measured physiologic arousal and real-time opinion ratings?
2) Which scenes of the film correspond to the sharpest change in physiologic arousal and real-time opinion ratings?
3) Is there any influence of prior knowledge of Mayan culture or astronomy on opinion ratings for different segments of the show?

Demographics

A total of 35 visitors participated in the study, completing pre-, post-, and during-viewing measures. Of those, 20 (57.1%) were female and 15 (42.9%) were male; 19 (54.3%) were age 30 to 49, 14 (40%) were age 50 and above, and 2 (5.7%) were age 18 to 29. Participants had a range of educational backgrounds. One (2.9%) had a high school education; 7 (20%) had attended community college, a technical school, or some college; 8 (22.9%) had a bachelor's degree; 4 (11.4%) had attended some graduate school; and 14 (42.9%) had a graduate degree.

Twenty-two (62.8%) participants were white or Caucasian; six (17.1%) were Asian American or Pacific Islander; four (11.4%) were Latino or Hispanic; two (5.7%) were Native American; and one (2.9%) was Nahuatl or other Latin American indigenous group. Four (11.4%) selected "other," and four (11.4%) identified within more than one category. Most participants (25, 71.4%) had visited Chabot previously, ten (28.6%) had not. Most (31, 88.6%) had seen a planetarium show previously, while the other four (11.4%) had not; and 27 (77.1%) had not seen *Tales of the Maya Skies* previously, seven (20%) had seen the film, and one (2.9 %) was unsure.

A participant was, therefore, most likely to be a white woman with a graduate degree, aged 30-49 who had previously visited Chabot and has seen a planetarium show before this visit, but not *Tales of the Maya Skies*.

Question 1: Which scenes of the film correspond to the highest and lowest measured physiologic arousal and opinion ratings?

Physiologic response to the film was measured over a total of 31 60-second segments of the film, with dependent variables measured being: mean heart rate (HR); respiratory sinus arrhythmia (RSA; a

parasympathetic measure to heart rate); skin conductance level (SCL); and number of skin conductance reactions (SCRs; defined as an increase of at least .05 microsiemens within a 1-3 second period). Table 3.1 outlines what took place in the narrative and visual effects during each 60-second segment of *Tales of the Maya Skies*.

Table 3.1: Summary of narrative content and visual/sound effects within each 60-second segment of Tales of the Maya Skies

Segment	Narrative	Visual
1	Introduction from Maya narrator about Maya stories	Darkness, spiraling snake, Milky Way, and bubbles in the darkness
2	Gods considering how to make the world; measuring the directions	Lightning; spiral of bubbles
3	Creation of Earth, mountains; Title Sequence	Crane surrounds screen; turtle moves toward viewers creating mountains and waterfalls,; Title Sequence
4	Location of Maya on Earth, in the jungle	Highlighting countries on globe; Zooming in through clouds, forest, to Chichen Itza and Maya ruins
5	Introduction of Maya; Identifying Maya constellations	Panning around the temple with thunder and lightning; Constellations appear in dark sky, highlighting Gemini as Owl
6	Identifying Maya constellations. Transition to creation of the world and the cave of Balankanche	Highlighting Orion as Turtle and Hearthstones of Creation; Pans down through trees into the cave
7	Creation of sky, earth, and underworld; Gods' attempts to make people from mud and wood	Panning around cave and its formations; Shadows on the walls show creating people
8	Gods make people out of corn; Transition to story of Hero Twins.	Shadows show corn people; Zoom into clay pot; Forest appears around edge in darkness; Hero Twins appear
9	Hero Twins as hunters and ballplayers. Introduction of dead father and the Underworld.	Twins shoot Macaw with blowgun, who rises into sky as Big Dipper. Twins playing ball.
10	Gods are angry and challenge Twins to ball game to Underworld; Twins begin journey	Underworld enters screen with voices of the Gods of Death; Twins ride Feathered Serpent constellation to Underworld; Narrator sings in Mayan.
11	Twins play ball against Gods of Death, winning through trickery. They plant, tend father's skull in ground.	Song ends. Twins and Gods of Death play ball; Bones clatter when Twins win. Twins plant skull of father. Narrator sings in Mayan.
12	Birth of the God of Corn; Description of the importance of Corn to the Maya.	Maya song continues; Roots and corn plant grow from skull.
13	Twins become the sun and the moon; Maya people viewing and counting the first sun and moon.	Twins rise into the sky as sun and moon. Panning to follow movement of first sun across sky, then first moon.
14	Scientific explanation of the cause of seasons on Earth	Sun blooms into a giant flower; View from space of Earth's tilt and movement to cause Seasons
15	Scientific explanation of the cause of seasons on Earth, as well as the rainy and dry seasons experienced by the Maya	View from space of Earth's tilt and movement to cause seasons
16	Maya methods for tracking movements of the	Line drawings of temples and placement of stakes

	sun	in the ground; Showing movement of shadows over a year
17	Maya discovery of the Equinox, Solstices, and Zenith Sun	Line drawings showing movements of shadows at these events.
18	Explanation of Maya calendar	Background of glyphs from calendar; Maya symbols representing each number, days, months, and year.
19	Maya creation of zero and complex, accurate calendar system	Maya symbols for zero and higher numbers; Zoom into Temple of the Warriors
20	Description of the Temple's alignment with the sun; Description of Temple of the Feathered Serpent	Pan around statue on Temple of the Warriors; Pan around top of Temple of Feathered Serpent
21	Description of number of steps on Temple, and the play of the Equinox sun on the steps	Viewing temple, sun sets making a shadow on the steps. Animated Feathered Serpent snakes down steps, onto ground, over dome.
22	Legend of Feathered Serpent ends; Transition to role of Maya rulers	Feathered Serpent splashes into well; Temple with Maya ruler at the top, panning around the ruler to view crowd.
23	Ability to predict solar eclipse; scientific explanation of what causes a solar eclipse	Zooms over ruler's head and up to the eclipse sun; View from space of moon passing between Earth and Sun
24	End of eclipse explanation; Role of Venus for Maya	Shadow caused by the moon from space; Back to the ruler on the Temple; Image of Venus as a star the Maya symbol
25	Watching and recording Venus's movements in the Western sky; relationship to corn planting and harvest	View of Venus's movements on West side of dome over the course of nine months
26	Venus's movements in Eastern sky; Legends of Venus; Introduction of El Caracol to study Venus	View of Venus's movements on East side of dome over the course of nine months; Maya glyphs and glowing wasp moving; El Caracol
27	Alignment of El Caracol; Explanation of why Venus's movements appear this way	Panning around El Caracol; Transition to view from space of Venus, Earth, and Sun
28	Explanation of why Venus disappears and cyclical nature of its movements	View from space showing movements of Venus, Earth, and Sun
29	Exiting Chichen Itza and stories of Maya; Describing Maya achievements in science	Original view of Chichen Itza temple, with storm, thunder, lightning; Zooming through the forest, clouds, to Earth from space.
30	Description of long count calendar and the connection of all things on Earth	Transition to silver, sparkling turtle with Ceiba tree on its back
31	Description of 7 million Maya living today; End of film	Video montage of present day Maya people. Bird flies off into the distance.

To assess the patterns of physiologic response to the film, an overall mean for the group of participants was calculated for each dependent variable within each 60-second segment of the film. These means were plotted chronologically to visually assess trends of where increases and decreases of each physiologic measure occurred relative to the show's narrative and visual effects.[1] Figure 3.1 presents the average heart rate and RSA of viewers throughout *Tales of the Maya Skies*.

[1] It should be noted that these data represent discreet points and that changes from point to point may not be as represented by the line graphs. Thus, for some of the analysis, trends were examined across larger segments.

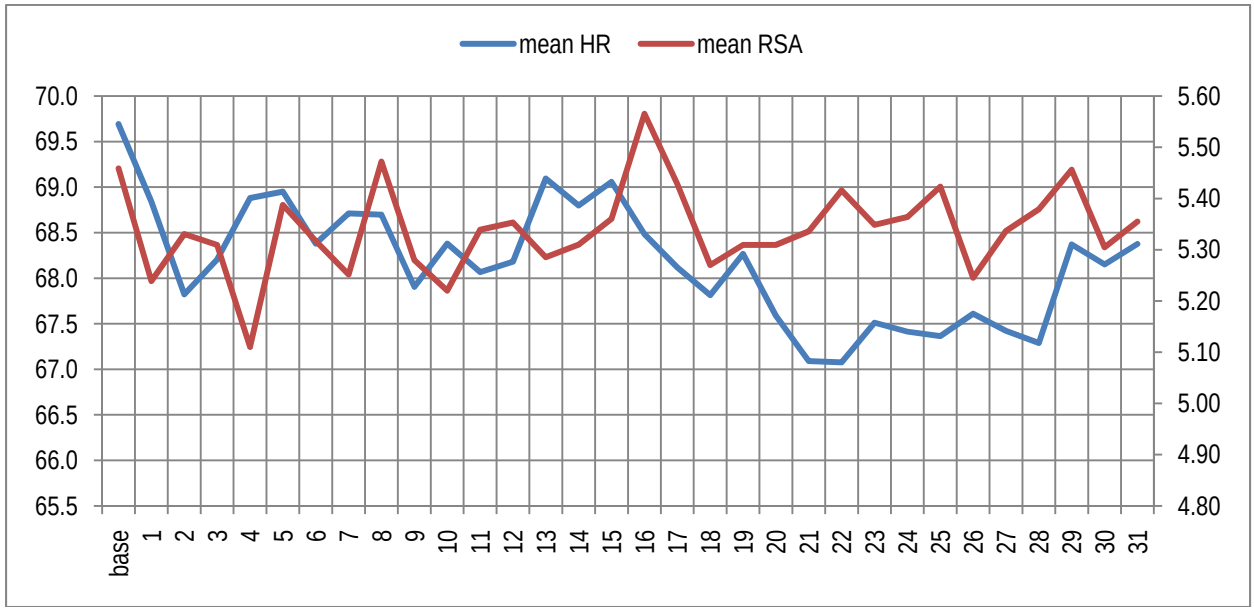


Figure 3.1: Mean heart rate and RSA by segment

During the film, mean heart rate across the group ranged from a low of 67.08 beats per minute to a high of 69.09 beats per minute. As is evident from Figure 3.1, RSA (a parasympathetic response) appeared to run counter to heart rate, serving to moderate physiologic reactions. The overall pattern of heart rate response to the film seemed to be starting at a high level, decreasing substantially during the middle of the show, and increasing again at the end.

The points of highest mean heart rate occurred at several segments during the show, most notably around Segments 4-5 (scenes zooming in through jungle to the ruins of Maya temples), 13-15 (space view of planetary movements to cause the seasons), and 29-31 (zooming back out through the forest, and closing sequences of the present day Maya). These sequences were some of the more disorienting in the film, moving viewers quickly through space in a way that (from researchers' experience and the pre-show announcements at Chabot) can cause dizziness or nausea. The lowest points of heart rate came between Segments 20-28, which presented several Maya temples aligned to solar and planetary movements, including an immersive experience of an animated serpent flying over the heads of the audience and into a well.

Looking at larger patterns across segments, there is a fairly stable heart rate up to Segment 15, when the heart rate begins a general downward path through Segment 22. At this point, the heart rate begins a rise to the end of the show. Segment 4 had the lowest RSA. The second half of the film had a lower overall mean than the first half. The greatest suppression (i.e., highest RSA) occurred between Segments 15 and 16 followed by the most severe shift (downward) in RSA over the next 2 segments.

The other type of physiologic response collected was skin conductance, which was measured by overall skin conductance level (SCL) during each 60-second segment, as well as the number of skin conductance reactions (SCRs; essentially, a sudden, substantial increase in conductance level) within a segment. These two measures are very much related to one another, but SCL measures an overall level of conductance, while SCR measures response to a stimulus--although in this case, all are non-specific

stimuli, as the research did not seek to link individual show elements to a response. In analysis, it was discovered that the equipment obtained very weak skin conductance readings for part/all of the show for a substantial number of participants. These readings were removed from analysis, with a threshold set of 2.0 microsiemens as a minimum SCL needed for inclusion in the data set. Figure 3.2 presents the mean SCL and number of SCRs for participants in the study.

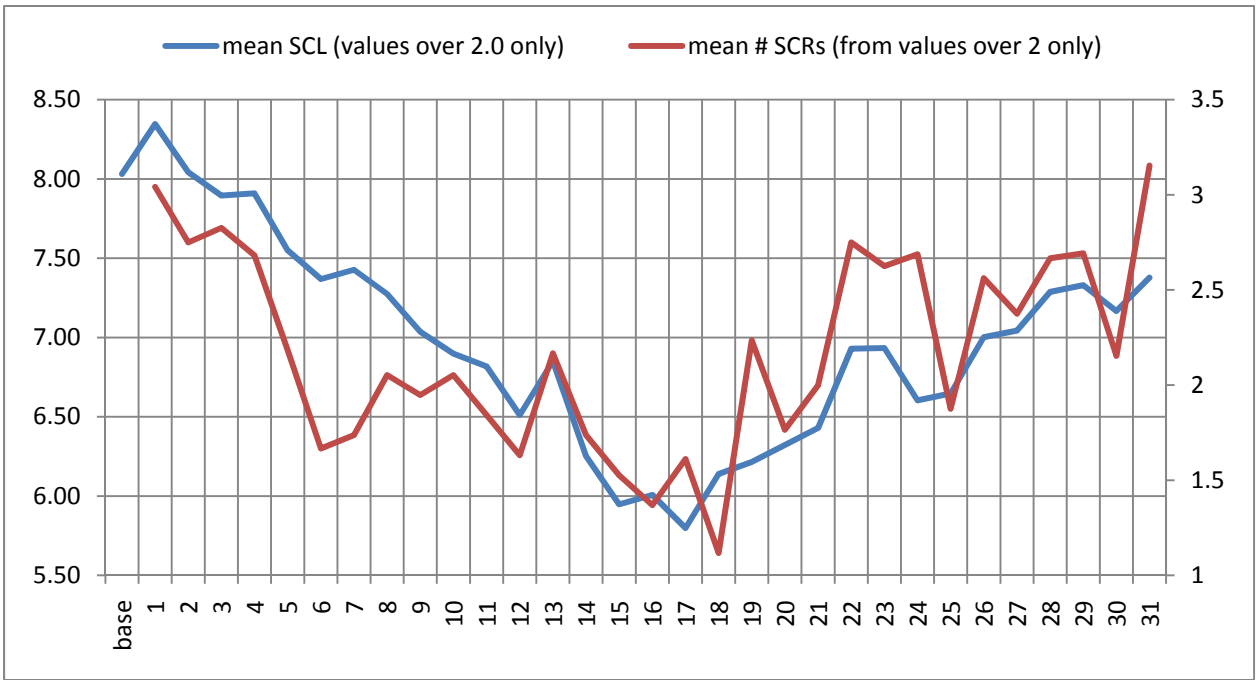


Figure 3.2: Mean SCL and number of SCRs by segment

As they measure similar phenomena, these two trend lines show a similar trajectory of viewers' skin conductance changes over the course of the film; with skin conductance steadily declining through the first half, and then steadily increasing over the last half of the film, paralleling the overall heart rate data. The scenes that begin viewers' increasing trend are around Segments 18-21, with the presentation of the Maya calendar, architecture, and alignment to planetary movements. Further, in the skin conductance measure, there is a rather sharp increase in SCL and SCRs at Segment 22, which contains the immersive visual of the serpent flying overhead and into the well. This may indicate that this visual experience created a greater number of reactions in visitors. Segments 15-17, which explain the solar reasons for seasons and simple line drawings of how the Maya first tracked the movement of the sun, led to the lowest SCL overall.

Viewers also provided a continuous rating of their opinion of the experience throughout the show, with ratings registering on a scale from 0 to 5. These continuous ratings were analyzed by calculating the mean opinion rating within each 60-second segment of the film. The pattern of mean ratings is shown in Figure 3.3.

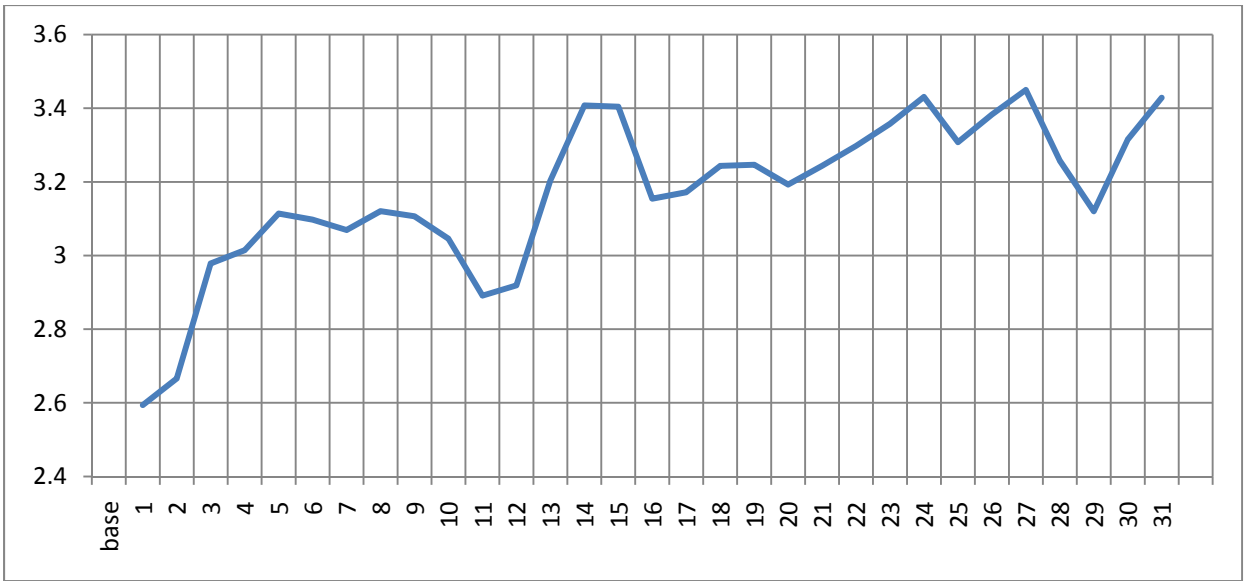


Figure 3.3: Mean opinion rating by segment

There is clearly a slightly different pattern to opinions than to heart rate and skin conductance measures, with ratings of the show generally increasing over the show, with sharp increases at scenes that were more preferred by viewers. The peaks of visitors' positive opinions of the show were at Segments 14-15 (explanation of Earth seasons from a planetary view), 24-27 (explanation of planetary reason for a solar eclipse, the movements of Venus in the sky, and the planetary reason for Venus's movement from a space view), and 31 (closing scene of the film, Maya today). The lowest points of visitors' ratings were Segments 1-2 (the opening of the show; rating dials were started at a neutral point of 2.5) and 11-12 (battle of Hero Twins in the underworld; birth of the God of Corn). These trends indicate that the viewers in this study greatly preferred the traditional planetarium aspects of the show, and were less happy with the cultural stories and narrative of the Maya people. This could explain the overall slowly decreasing heart rate, SCL, and SCRs across the first half of the film and then the slow increase following Segment 15 through to the end.

Looking at the relationship between the highs and lows of these measures, there does not appear to be a direct match between the physiologic data and the opinion ratings. It appears that visitors' opinions related strongly to content of the story and presentation, whereas physical response related more to immersive experiences of the visuals, including moving quickly through the forest, around temples, lightning strikes, and visuals surrounding the screen and moving overhead.

Question 2: Which scenes of the film correspond to the greatest increases or decreases in physiologic arousal and opinion ratings?

Another way to consider these data for evidence of effect of scenes is to examine the degree of change from one segment to the next. Since heart rate and skin conductance are continuous measures, a greater a change in average response between two segments indicates that segment had a stronger effect on the viewers' physiologic or opinion. Figure 3.4 shows the patterns of change for the four physiologic measures assessed. A change level at the zero line indicates no change from the previous

segment, a positive level indicates an increase from the previous segment, and a negative level indicates a decrease from the previous segment.

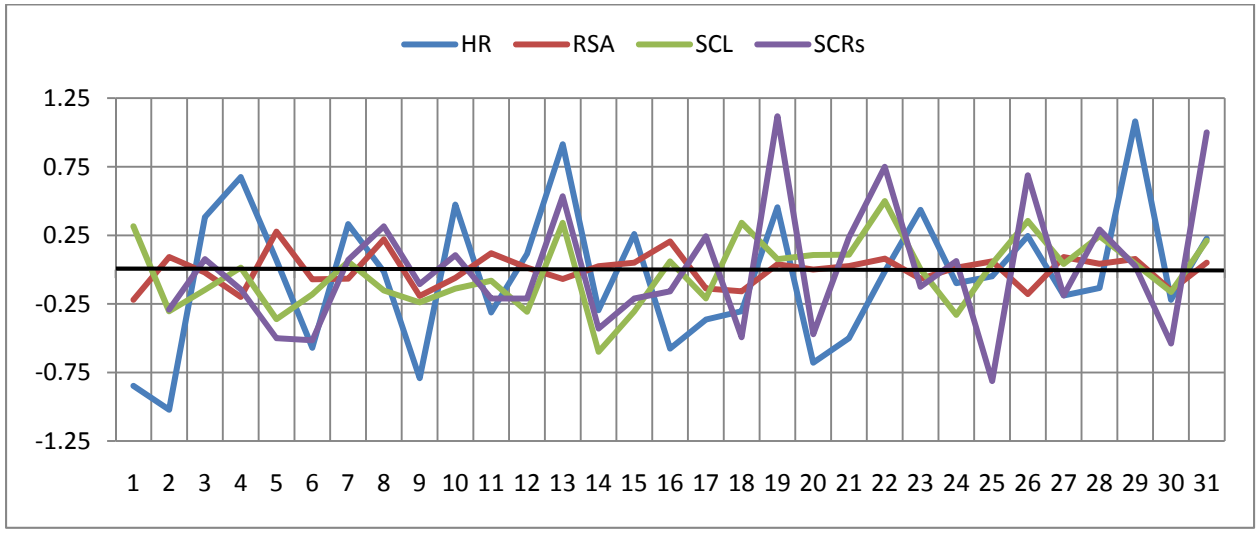


Figure 3.4: Amount of change in means between segments for physiologic measures

Seen in this way, the patterns and commonalities in the physiologic responses are more evident, highlighting segments of the film where there were sharp increases or decreases in arousal. Specifically, there were relatively sharp increases in heart rate, SCL, and SCRs at Segments 7-8 (movement through Cave of Balankanche, zooming into clay pot, transition to a new scene), 13 (movement of the first sun and moon across the dome sky), 19 (explanation of the use of zero in Maya counting, zooming into a Maya temple), 21-23 (serpent sliding down temple and into well, zooming into temple and over Maya ruler's head), and 25-26 (movement of Venus in east and west, glowing wasp moving across glyphs)

Points in the sequence that seemed to cause sharp declines in physiologic arousal measures included Segments 9 (Hero Twins playing ball in the forest), 14 (scene change to explanation of seasonal movements), 20 (scene change between two temples), 24-25 (scene change from ruler at temple to story of Venus moving in the western sky), and 30 (view of earth from space, change to turtle carrying tree moving toward audience). Interestingly, most of these sharp declines correspond to scene changes in the show; moments when the screen darkened and the story shifted to a new idea. It makes sense that these may be moments when the body can momentarily relax, and physiologic arousal measures decrease sharply as one scene ends and the story of the next begins.

Some interesting changes in patterns include an increase of heart rate with a decrease in the other indicators in segment 4, although the indicators all increase together after segment 6. The inverse happens between segments 15 and 16 where heart rate drops as other indicators rise.

A depiction of changes between segments of opinion ratings is presented in Figure 3.5.

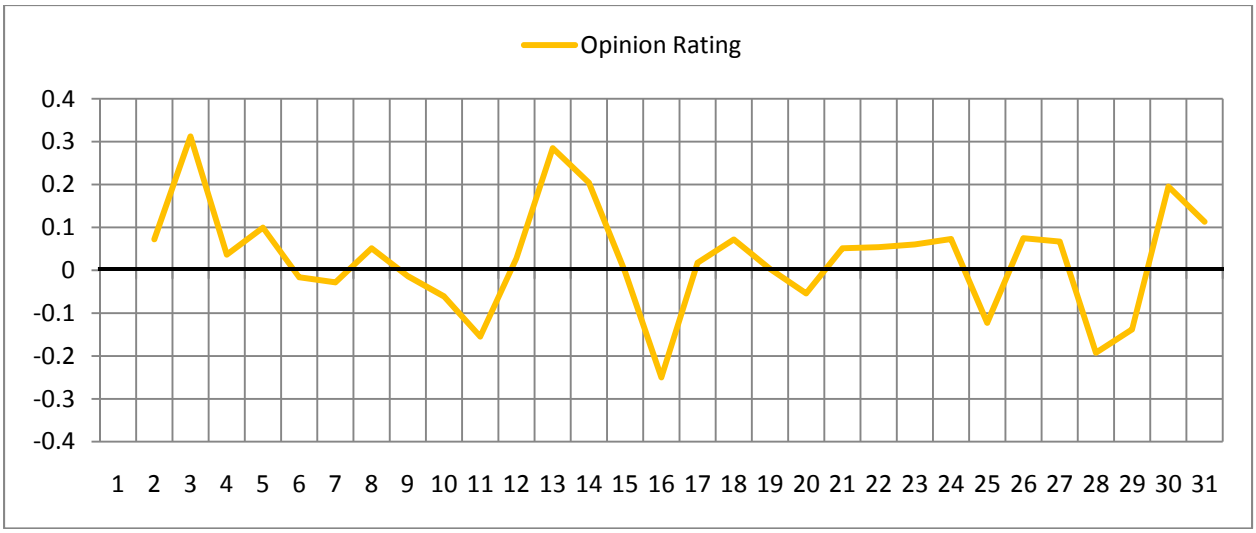


Figure 3.5: Amount of change in mean opinion ratings between segments

In terms of visitors' opinions of what they were viewing, the sharpest positive change occurred around Segments 3 (turtle emerging to create mountains, moving through mountains and waterfalls), 13 (first sun and moon moving across the dome), 17 (line drawings, explanation of the zenith sun), 26 (Venus moving in the east and wasp moving across glyphs on the screen), and 30 (discussing long-count calendar, showing Earth from space, shimmering turtle with Ceiba tree). The sharpest negative change between segments were at Segments 11 (Hero Twins in the Underworld), 16 (line drawings of Maya tracking movement of sun), and 28 (explanation of cyclical nature of Venus's movements).

The longest period of strongly changing opinion ratings occurred from Segment 11 through Segment 16, including both increasing and decreasing opinions. Other large swings in opinion ratings occurred between Segments 28 and 31 and Segments 2 through 5. Otherwise, opinions remained fairly stable with low levels of change (i.e., hovering around the zero line) between segments, with a tendency to be slightly increasing (i.e., slightly above the zero line).

Taken together, the depictions of the degree of change between film segments from physiologic and opinion data (Figure 3.6), show points of convergence and divergence in the responses of visitors to the show.

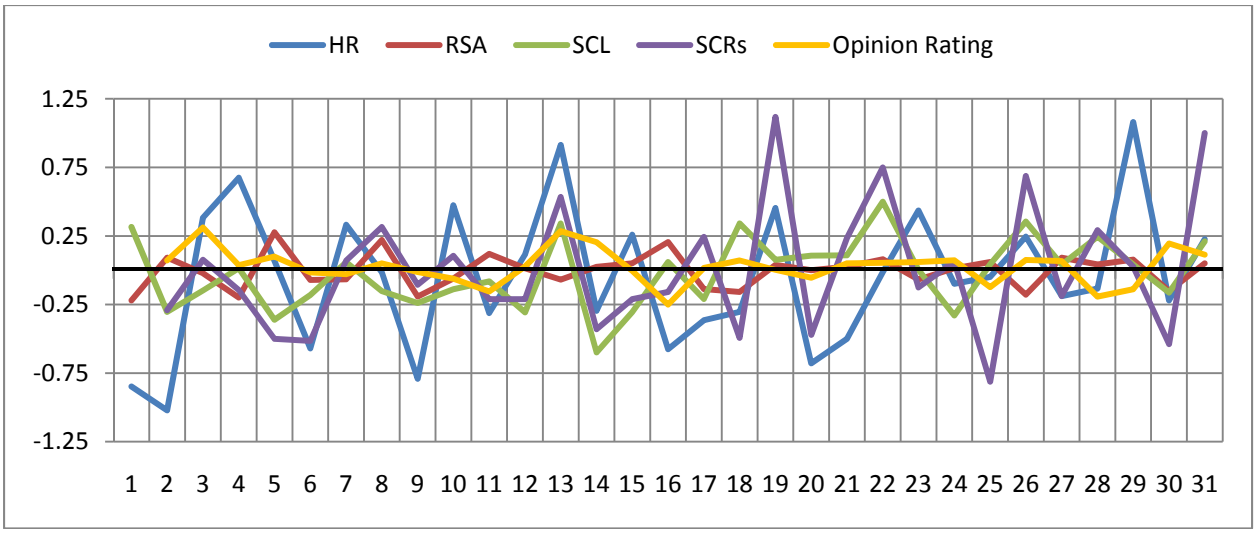


Figure 3.6: Amount of change in mean measurements between segments

Around Segment 13 (first sun and moon moving across the dome), for instance, heart rate, SCL, SCRs, and opinion rating all had rather sharp change in direction, going from a decrease or no-change to a substantial increase. In other areas, such as Segments 28 and 29 (explanation of Venus from space; zooming back out through the forest), the physiologic and opinion data are in more conflict. In these segments, data showed physiologic arousal had an increase, but opinions shifted to decreasing trends.

The other points of interest in this combined visual include the disparity in Segment 4 (zooming in to Chichen Itza through the jungle) of heart rate versus the other measures, and all measures shifting to either decreasing or steady trends in Segment 9 (Hero Twins playing ball with Gods of Death). One interesting observation is that change in opinion appears to follow heart rate in general, but not necessarily by every segment. This is an area that needs more inquiry.

Question 3: Is there any influence of prior knowledge of Mayan culture or astronomy on opinion ratings for different segments of the show?

Based on the pre-show questionnaire, visitors were grouped into categories of high, medium, or low levels of knowledge about the Maya and about astronomy, based upon scoring their answers to questions on each topic. To explore an emerging hypothesis that opinion ratings of the show were connected to the narrative content of the film, with a preference for traditional planetarium show segments over segments focused on Maya culture and mythology, we compared the opinion rating trends of viewers based upon these characteristics.

In terms of incoming astronomy knowledge, statistical comparison (ANOVA) of mean opinion ratings across the three groups showed that the opinion ratings of the groups were not statistically different in any single show segment. However, plotting the trends of those opinions shows that the overall trends had some differences in pattern between the three groups (Figure 3.7).

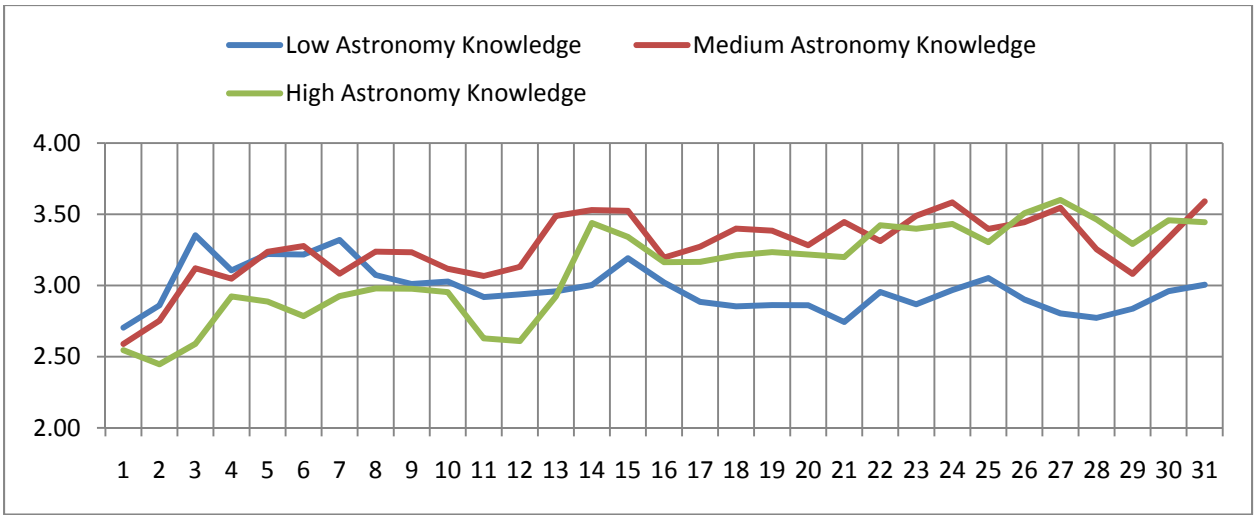


Figure 3.7: Mean opinion ratings by astronomy knowledge cluster

For instance, from Segments 4 through 6, those with low and medium astronomy knowledge were increasing their opinion ratings, while the high astronomy knowledge viewers were decreasing their ratings. This section of segments corresponded to the arrival at Chichen Itza and introduction of the stories of Maya creation of the stars and constellations.

Another contrast is around Segments 11-12, which showed decreasing preference by those with high knowledge, but maintaining relatively steady, higher preference by those with low and medium knowledge. These were the segments depicting the Hero Twins battle in the underworld, saving of their father's spirit, and his rebirth as the God of Corn; this section was wholly focused on the Maya creation stories. Following this segment, the high astronomy knowledge group has a sharp increase in their opinions through Segments 13-15, which corresponds to the first movement of the sun and moon in the sky and a transition to the planetary view explaining the cause of the seasons on Earth – more traditional planetarium presentations.

Finally, another contrast of interest is between Segments 25 and 27, where the low astronomy knowledge group is decreasing their opinion, while the high and medium groups are increasing their ratings. This section explains the movements of Venus in the eastern and western skies, as well as the architecture of the Maya observatory used to study this planet.

Overall, it appears that low astronomy knowledge was the most consistent in terms of opinion with the most common trend line. Those in the medium astronomy knowledge group appeared to have the more positive opinions of the show overall and most consistently. Initial opinion of the high astronomy knowledge group was lowest of the three, but increased over the second half of the film.

A similar comparison based upon levels of incoming knowledge of the Maya was run. Again differences in mean ratings within any individual segment were not statistically significant (ANOVA), but there are some patterns in the overall trends of the data (Figure 3.8).

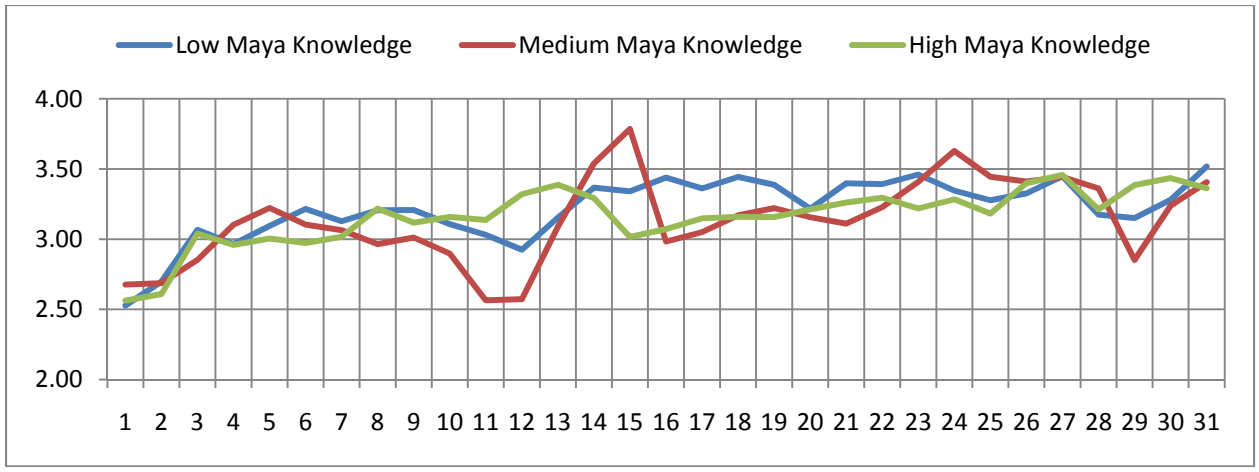


Figure 3.8: Mean opinion ratings by Maya knowledge clusters

Overall, all three levels of knowledge followed similar trends and patterns in opinion. The greatest differences appear around the span of Segments 10 through 16, where those with medium Maya knowledge seemed to make sharper changes in opinions, dropping more sharply during Segments 11 and 12 (the story of the Hero Twins and God of Corn), and increasing more sharply over Segments 13-15 (the planetarium explanation of the seasons). Those with high Maya knowledge, in contrast, showed some increase around Segment 12 (the birth of the God of Corn). All three groups had a gradual increase in opinion patterns from the beginning to the end of the film.

Discussion: Study 3

These data shed light on the specific segments of *Tales of the Maya Skies* that led to stronger and weaker physiologic arousal, as well as more positive or negative opinion response. Taken together, the patterns in these data point to aspects of the show's physical or cultural immersion that seemed to most influence this real-time response. One major trend was the stronger physiologic response, particularly in heart rate, during physically immersive scenes that involved rapid movement involving the entire dome screen, such as zooming in or out of an environment and panning around environments. Such experiences are known to be physically disorienting or dizzying for some viewers, and physiologic response data (particularly heart rate) seem to validate that. Scenes that were immersive with visual effects (i.e., the feathered serpent on the temple stairs), but not physically disorienting, seem to have little effect on heart rate, but have a much more pronounced effect on arousal measured through skin conductance.

The patterns of physiologic response also indicate that the natural moments of rest in a film, transitions between scenes, also allow viewers to relax and their physiologic arousal levels to decrease. The common points where viewers' physiologic measures sharply decreased were centered around such scene changes and transitions. Increases in arousal, however, seem to cluster around most of the physically immersive scenes involving panning or zooming around environments; these were the scenes that caused the greatest degree of arousal increase (as opposed to raw arousal level).

There was also a lack of strong relationship between viewers' real-time opinions of the film and their physiologic response. Viewers did not rate most positively the most physically immersive segments of

the show. Rather, the patterns suggested their highest ratings were given to segments that were most like traditional planetarium offerings, explaining scientific phenomena from a space-view. Conversely, they rated lowest scenes most representative of the cultural immersion of the story. Much like the results of Study 2 presented earlier, there were also trends suggesting that those viewers who entered with higher astronomy knowledge more preferred traditional planetarium elements, and disliked the cultural wrapper of the show.

This highlights the complexity of studying visitor opinion, which was affected by the narrative arc of the film as much, if not more, than its physically immersive qualities and visual effects. As visitors respond in real-time to their overarching opinion about a show, all factors including content, narrative elements, and visual effects will come into play in a complex way. Further study would be needed to tease these factors apart.

Conclusions

Three overarching questions drove the research. The questions, and the sub-questions that were asked to address the overarching questions, are answered below. Overall, there is an impact of physical immersion on learning. The "cultural wrapper" does make a difference depending on language, and somewhat on entry knowledge levels and interest, but not very much based on age or sex.

I. What is the impact of physical immersion on learning?

1) Are there differences, based on the size of the screen the show is viewed on, in viewer perception of immersion?

Yes. The Dome appears to create a more immersive experience as measured by the immersion scale, communicates concepts better, and creates a greater interest in learning more when compared to a large screen (movie theater).

2) Are there differences, based on the size of the screen the show is viewed on, in viewer perception of the overall show and visuals of the show?

Yes. All three screen formats led to desired messages and positive satisfaction. Consistently, the full-dome theater was the strongest followed by the television screen with the large screen being the least effective.

3) Are there differences, based on the size of the screen the show is viewed on, in viewer learning?

Yes. The full-dome theater is a more effective medium at conveying scientific concepts and inspiring an interest to learn than movie theater-style screen or television.

II. What is the influence of the "cultural wrapper" on learning?

1) Are there differences, based on the language of the show, in incoming viewers self-reported interest in Mayan culture, knowledge of Mayan culture, connection to Mayan culture, connection to astronomy, and knowledge of astronomy?

Yes. The mean scores for self-reported knowledge of Mayan culture suggest that participants felt they have a lower knowledge of Mayan culture than they do interest in Mayan culture. All items had means below four (negative) with the exception of Spanish language viewers on the item *Daily life of the ancient Maya people*. Spanish language viewers rated their knowledge at higher levels than English language viewers on each item. English language viewers of the show had lower standard deviations on each item suggesting a more consistent response.

2) Are there differences, based on the language of the show, in viewer perceptions of the overall show, visuals of the show, and what they liked about the show?

Yes. Viewers of the Spanish language film had significantly higher self-reported interest for each item. Differences in mean for interest were significant for Mayan astronomy; for the ancient Mayan culture; for daily life of the ancient Maya people; and for present day Mayan culture.

3) Are there differences, based on the language of the show, in viewer learning?

Yes. There are differences, based on the language of the show, on viewer learning. As measured by what participants felt the show communicated, Spanish language viewers rated each item higher than English language viewers, with four items being rated significantly higher. English language viewers stated the show told *A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society* significantly higher than Spanish language viewers, while Spanish language viewers rated *A story about the Maya and their culture, including their knowledge and use of astronomy* as the highest item the story told.

4) Are there differences, based on connection to Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Yes. The results indicated statistically significant differences between groups on the positive perceptions of the show in that those with high connection to Mayan culture had significantly higher scores than those with low connections.

5) Are there differences, based on connection to Mayan culture, in viewer learning?

Some. Those who had high levels of connection to Mayan culture felt the show was better at communicating some elements of the culture than did other respondents. Regarding how much the show told a story, there were no significant differences between groups.

6) Are there differences, based on prior knowledge of astronomy, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Yes. There were differences between low, medium and high scoring groups in prior knowledge of astronomy for each of the four frames of the show. Those with low prior knowledge of astronomy liked the show significantly more than those with high entry levels of knowledge of astronomy.

7) Are there differences, based on prior knowledge of astronomy, in viewer learning?

Some. There were significant differences between groups on what the movie communicated, and no significant differences between groups related to how much the show told a story.

8) Are there differences, based on interest in Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Yes. Interest in Mayan culture had a significant effect on the positive perceptions of the show. High levels of prior knowledge of astronomy had an additive effect on these scores. Post-hoc analysis indicated that those in the high interest in Mayan culture had significantly higher scores than those in the medium and low interest in Mayan culture. High levels of interest in Mayan culture had a reducing effect on the positive perceptions of the show. Post-hoc analysis indicated that those with high interest

in Many culture had significantly lower scores than those with low interest. Interest in Mayan culture did not have a significant effect on the difference between medium and low, and medium and high groups. The high interest group was significantly more positive in their rating of visuals than the medium and low; medium group was significantly more positive in their rating of visuals than the low interest group. Interest in Mayan culture was significant between groups in what they felt the story was about.

9) Are there differences, based on interest in Maya culture, in viewer learning?

Some. Interest in Mayan culture had a significant effect on each of the items measuring topics the film communicated. Interest in Mayan culture did not have a significant effect for any of the four descriptions of the story the movie told.

10) Are there differences, based on interest in astronomy, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Yes. Those entering with lower interest in astronomy tend to have significantly more positive perceptions upon exiting than those with high interest in astronomy.

11) Are there differences, based on interest in astronomy, in viewer learning?

Yes. Those visitors entering with scores placing them in the lower interest in astronomy category show significantly more positive orientation to the messages of the show upon exit than do those with high interest in astronomy.

12) Are there differences, based on age, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Some. Those 50 years old and above had significantly more positive orientations toward Mayan astronomy, culture, daily life, and present day culture.

13) Are there differences, based on prior knowledge of Mayan culture, in viewer perception of the overall show, visuals of the show, and what they liked about the show?

No. There were no significant differences on viewer perceptions based on prior knowledge.

14) Are there differences, based on prior knowledge of Mayan culture, in viewer learning?

No. There were no significant differences in viewer learning based on prior knowledge.

15) Are there differences, based on age, in viewer learning?

Some. Those 50 years old and above has a higher perception of learning than those age 18-29 years. Those ages 30-49 did not differ significantly from the other two groups.

16) Are there differences, based on sex (male or female), in viewer perception of the overall show, visuals of the show, and what they liked about the show?

Generally, no. In terms of perception of the show, visuals, and what they liked about the show, there were only two items that showed statistically significant differences between males and females. On both of these, females rated the item more positively than did males. The first item was on what the film communicated: *Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture* and the second was what they liked about the show: *A story about astronomical concepts and how the Maya learned these*.

17) Are there differences, based on sex (i.e. male or female), in viewer learning?

No. There were no significant differences between males and females in terms of viewer learning.

III. What parts of the physically immersive show create a strong response?

1) Which scenes of the film correspond to the highest and lowest measured physiologic arousal and real-time opinion ratings?

It appears that visitors' opinions related strongly to content of the story and presentation, whereas physical response related more to immersive experiences of the visuals, including moving quickly through the forest, around temples, lightning strikes, and visuals surrounding the screen and moving overhead.

2) Which scenes of the film correspond to the sharpest change in physiologic arousal and real-time opinion ratings?

The sharpest positive change occurred around segments showing the turtle emerging to create mountains, moving through mountains and waterfalls, the first sun and moon moving across the dome, the explanation of the zenith sun, Venus moving in the east and wasp moving across glyphs on the screen, and discussing long-count calendar, showing Earth from space, shimmering turtle with Ceiba tree. The sharpest negative change between segments were of the Hero Twins in the Underworld, the line drawings of Maya tracking movement of sun, and the explanation of cyclical nature of Venus's movements.

3) Is there any influence of prior knowledge of Mayan culture or astronomy on opinion ratings for different segments of the show?

A little. It appears that low astronomy entry knowledge was the most consistent in terms of opinion with the most common trend line. Those entering in the medium astronomy knowledge group appeared to have the more positive opinions of the show overall and most consistently. Initial opinion of the high astronomy knowledge group was lowest of the three, but increased over the second half of the film. Those with high astronomy knowledge seemed to prefer those segments that were most like traditional planetarium shows, and least prefer those segments that focused on the cultural stories of the Maya. Differences in mean ratings by entry knowledge of the Maya within individual segments showed no significant differences, but there were some slight overall trends in the data with low and high Maya knowledge most closely intertwined and related.

Implications

This research has helped highlight several important trends about *Tales of the Maya Skies* specifically, and about the impacts of full-dome theater environments more generally. A major conclusion of this research is that the full-dome environment does have a unique impact on learning, immersion, satisfaction, and overall viewer experience. When different individuals see the same show in three different conditions, the learning, satisfaction, and sense of immersion are all significantly higher in the full-dome setting. Further, the nature of the film in this immersive environment does seem to affect visitors' physiologic experience and responses – raising heart rate in sequences that are physically disorienting and raising skin conductance at the most striking visual effects. This finding, however, must be tempered with the observation that this is not a true comparison by individuals of the three formats, as any one visitor saw the film in only one of the three settings.

While this initial research elucidated these basic questions, it has also raised further questions that cannot be answered here. For one, there was a limitation of the formats tested in this study. While there was a control across the experience by using the exact same film, it was found that this exact replication does not account for the design differences inherent in each production format. It became clear that this was not just about degree of physical immersion, but that it particularly had an influence on pacing. A scene shown at exactly the same speed may feel nauseating in the full-dome environment, but may feel plodding and slow in a standard theater or TV experience. For future research, it would be valuable to test films equivalent in narration, story, content, and visual effects, but adapted for better alignment with the different environments to account for contextual variables.

This study also indicates that there is an impact to using a "cultural wrapper" to tell a scientific story, with different populations responding differently to the production because of this narrative approach. Telling a scientific story through a cultural lens, embedding science content in the story of a people, their lives, and their achievements, was a strategy that resonated more with some viewers than others. Most notably, those who viewed *Tales of the Maya Skies* in its Spanish-language version had a much more positive response to the film across the areas measured – perceived learning and satisfaction. Similarly, those who self-reported that they entered the film with a high interest and connection to the Maya also had stronger positive responses to the film; whereas those with low levels of these variables did not express as strong learning or satisfaction.

In fact, our research suggests that the cultural wrapper created a disconnect for some planetarium visitors, who seemed to desire or be looking for the "real astronomy" in the production. Comparisons showed that those who came to the show with high levels of astronomy knowledge reported less learning and less positive perceptions of the show. In a similar vein, the real-time opinion data collected showed that the highest average ratings and the peak heart rate moments occurred at the segments of the film that were most like a traditional planetarium presentation of the movement of the sun, planets, and stars. Further, viewers with high incoming astronomy knowledge showed pronounced pattern of this type of opinion data.

This finding may present a challenge for planetarium and science center staff who seek to try this approach for future films. The *Maya Skies* project team and Chabot specifically developed this film with a specific intention to break the mold of traditional planetarium show and to draw and reach new audiences. These results indicate that this approach is indeed beneficial for reaching new audiences or audiences with a particular connection to the culture in question. However, it is worth noting that it can

cause lower satisfaction and a disconnect for those who come to the center looking for a traditional planetarium experience. This could, however, be a positive opportunity; knowing this issue is potentially present, a planetarium could help shift expectations among visitors regarding planetarium productions, addressing existing expectations so that the visitor is prepared for and even desires the alternative presentation. That such a tension exists and should be acknowledged and considered at the outset of production planning, as it was persistent across our studies.

Tales of the Maya Skies specifically showed an interweaving of several distinct themes, facts, and stories about the Maya people, astronomical facts, and the connection of astronomical knowledge to their daily lives. In fact, the research showed that it proved quite difficult for people to distinguish a single main message of this film, with the varying narrative threads all intermingling with relatively equal weight for participants. Overall, however, it seemed that the use of the cultural wrapper for the narrative was powerful in shaping the story and came through quite strongly. When asked about astronomy messages conveyed, the top two responses related to the cultural story around the concepts, rather than just the astronomy in isolation. However, when asked to place priority on which of four "big ideas" was most emphasized by the film, the results were split rather evenly across the options. There was little sense that it was any more a story of Maya culture (including their astronomy knowledge) than a story of astronomical concepts (including Maya knowledge of these). Of the many embedded stories and messages of this film, there was not one unifying message that seemed to rise above for viewers; it was instead a collection of these ideas.

Finally, this research indicates that the physiological and real-time opinion measurement methods used in the study have promise as measurement tools for informal learning environments. Although requiring a high time-investment by researchers and a limited number of participants who can be included at one time, the method provided new insights into the real-time experiences of visitors within the context of the learning experience. The data produced allowed a teasing apart to understand visitor response in-the-moment of experience that deepened our understanding of the post-experience reports. These methods allowed for an insight into experience and at a level of detail that would be impossible to capture through self-reported measures alone. Future studies using these tools may allow for refinement in the questions asked of these data, building upon the initial findings here.

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Appendix A: Study 1 Instruments

Pre-Show Questionnaire

Where did the ancient Maya live (in today's terms)?

- □ Peru, Bolivia, Colombia
- □ Australia, New Zealand, Tasmania
- □ Arizona, New Mexico, Utah
- □ Thailand, Vietnam, Cambodia
- □ Mexico, Belize, Guatemala

When approximately was the height of the ancient Mayan culture?

- □ 2000 to 1700 BC
- □ 1000 to 700 BC
- □ 600 to 900 AD
- □ 1500 to 1800 AD

How did the ancient Maya live?

- □ Mostly on farms, near small cultural town centers
- □ Small, family subsistence farms
- □ Nomadic tribes roaming the countryside
- □ Large cities with farms around them
- □ Floating coastal cities

What are the Maya known for? (Check all that apply)

- □ Defeated early European explorers in large battle
- □ Created a sophisticated calendar
- □ Developed skilled fishing techniques
- □ Astronomical knowledge
- □ Were early explorers of the seas
- □ Built large cities
- □ Invented explosives

What is the status of Maya today?

- □ The Maya still live in their original regions, but also elsewhere in the world.
- □ The Maya were extinguished by early European settlers in the 1500s.
- □ The Maya lived until about 1800, then vanished due to disease.
- □ The fate of the Maya is unknown today.

As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?

- □ Every day at noon
- □ Only on the first day of summer
- □ Only on the first day of winter
- □ On both the first days of spring and fall
- □ Never from your current location

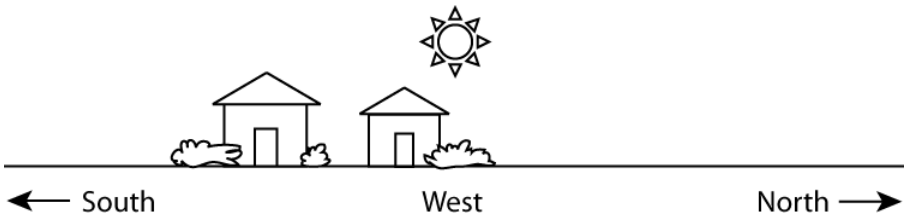
When the Moon appears to completely cover the Sun (a Solar Eclipse), the Moon must be at which phase?

- □ Full
- □ New
- □ First Quarter
- □ Last Quarter
- □ At no particular phase

Where does the Sun's energy come from?

- □ Nuclear fusion:
  The combining of light elements into heavier elements
- □ Nuclear fission:
  The breaking apart of heavy elements into lighter ones
- □ Thermal heating:
  The glow from molten rocks
- □ Ambient heating:
  Heat left over from the Big Bang

On September 22nd, in North America, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?



- □ Farther south
- □ In the same place
- □ Farther north

Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

- □ North Star, Moon, Sun, Venus
- □ Sun, Moon, Venus, North Star
- □ Moon, Sun, Venus, North Star
- □ Moon, Sun, North Star, Venus
- □ Moon, Venus, Sun, North Star

Please tell us about yourself:

Have you ever seen a planetarium show before?

□ Yes □ No □ Not Sure

Have you ever seen *Tales of Maya Skies* before?

□ Yes □ No □ Not Sure

Have you ever visited Chabot Space & Science Center before today?

□ Yes □ No □ Not Sure

Are you male or female?

□ Male □ Female

What year were you born? (ex. 1975): __ __ __ __ __ __ __ __

What ethnicity would you describe yourself as? (Check as many as apply)

- □ Asian American or Pacific Islander
- □ Black or African American
- □ Latino or Hispanic
- □ Native American or indigenous
- □ Maya
- □ Nahuatl or other Latin American indigenous group
- □ White or Caucasian
- □ Other/mixed (please describe) _____

What is the highest level of formal education you have completed? (Check one)

- □ Elementary or middle school
- □ Some high school
- □ High school diploma or equivalent
- □ Community college or some college
- □ Bachelor's degree
- □ Some graduate school
- □ Graduate degree
- □ Technical school

THANK YOU!

Immediate-Post Questionnaire

For each pair of adjectives below, check the box that represents how you would describe *Tales of the Maya Skies*. The closer a box is to a word, the more strongly you think that word describes the show.

Overall, how would you describe *Tales of the Maya Skies*?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Objective (fact-based)	☐	☐	☐	☐	☐	☐	Subjective (opinion-based)
Stimulating	☐	☐	☐	☐	☐	☐	Dull

How would you describe <u>the visuals</u> in the show?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Supported the story	☐	☐	☐	☐	☐	☐	Distracted from the story
Complicated	☐	☐	☐	☐	☐	☐	Simple

Please rate the degree to which *Tales of the Maya Skies* made you feel the following things:

While I was watching *Tales of the Maya* Skies, I felt…

	Not at all						Completely
I was surrounded by images and sound.	1	2	3	4	5	6	7
I was in the middle of the experience.	1	2	3	4	5	6	7
I was watching a program.	1	2	3	4	5	6	7
I was in a program.	1	2	3	4	5	6	7
I was transported to a different place.	1	2	3	4	5	6	7
My body was here but my senses were taken somewhere different.	1	2	3	4	5	6	7
I was visiting a different place and time.	1	2	3	4	5	6	7

List three main ideas that you learned about the stars, sun, and planets from watching *Tales of the Maya Skies*.

1. _____
2. _____
3. _____

Please tell us about three key ways that the Maya used knowledge about astronomy in their daily lives.

1. _____
2. _____
3. _____

What did the story of *Tales of the Maya Skies* communicate to you?

Please rate the extent to which you felt the show effectively communicated each of the following:

	Not at all						Completely
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	1	2	3	4	5	6	7
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	1	2	3	4	5	6	7
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	1	2	3	4	5	6	7
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	1	2	3	4	5	6	7
By observing the patterns of the sun, moon and planets, the Maya created a precise, accurate calendar that marked the seasons.	1	2	3	4	5	6	7
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	1	2	3	4	5	6	7
Corn was so important to the Maya that it played a strong role in origin stories.	1	2	3	4	5	6	7
The night sky represents the origin story of the Maya.	1	2	3	4	5	6	7

You can learn about things in a lot of different ways in your daily life – from newspapers, magazines, books, radio, TV, the internet, etc. Thinking about all of the places you could learn things, **please rate how much you would like to learn more about each of the following topics…**

	Strongly Disagree						Strongly Agree
Astronomy in general.	1	2	3	4	5	6	7
Movement of the sun and planets.	1	2	3	4	5	6	7
Understanding the night sky as observed from earth.	1	2	3	4	5	6	7
How stars, planets, and other astronomical elements affect life on Earth.	1	2	3	4	5	6	7
Indigenous or native knowledge or ways of knowing	1	2	3	4	5	6	7
Connections between indigenous knowledge and Western science	1	2	3	4	5	6	7
The process of how native knowledge is created	1	2	3	4	5	6	7
Differences between native or Indigenous knowledge and Western science	1	2	3	4	5	6	7
Maya culture and history	1	2	3	4	5	6	7
Maya architecture	1	2	3	4	5	6	7
The daily life of Maya	1	2	3	4	5	6	7
Maya accomplishments in astronomy	1	2	3	4	5	6	7
The Maya calendar	1	2	3	4	5	6	7

Can we contact you in a month or two to find out what you think about your planetarium experience? We will not use your contact information for any other purpose.

☐ Yes ☐ No

First Name: _____

Email: _____

and/or

Phone number: _____

Delayed-Post Questionnaire

List the main ideas that you learned about the stars, sun, and planets from watching *Tales of the Maya Skies*:

What are the key ways that the Maya used knowledge about astronomy in their daily lives?

What did the story of *Tales of the Maya Skies* communicate to you?

Please rate the extent to which you felt the show effectively communicated each of the following:

	Not at all						Completely
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	1	2	3	4	5	6	7
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	1	2	3	4	5	6	7
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	1	2	3	4	5	6	7
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	1	2	3	4	5	6	7
By observing the patterns of the sun, moon and planets, the Maya created a precise, accurate calendar that marked the seasons.	1	2	3	4	5	6	7
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	1	2	3	4	5	6	7
Corn was so important to the Maya that it played a strong role in origin stories.	1	2	3	4	5	6	7
The night sky represents the origin story of the Maya.	1	2	3	4	5	6	7

You can learn about things in a lot of different ways in your daily life – from newspapers, magazines, books, radio, TV, the internet, etc. Thinking about all of the places you could learn things, **please rate how much you would like to learn more about each of the following topics…**

	Strongly Disagree						Strongly Agree
Astronomy in general.	1	2	3	4	5	6	7
Movement of the sun and planets.	1	2	3	4	5	6	7
Understanding the night sky as observed from earth.	1	2	3	4	5	6	7
How stars, planets, and other astronomical elements affect life on Earth.	1	2	3	4	5	6	7
Indigenous or native knowledge or ways of knowing	1	2	3	4	5	6	7
Connections between indigenous knowledge and Western science	1	2	3	4	5	6	7
The process of how native knowledge is created	1	2	3	4	5	6	7
Differences between native or Indigenous knowledge and Western science	1	2	3	4	5	6	7
Maya culture and history	1	2	3	4	5	6	7
Maya architecture	1	2	3	4	5	6	7
The daily life of Maya	1	2	3	4	5	6	7
Maya accomplishments in astronomy	1	2	3	4	5	6	7
The Maya calendar	1	2	3	4	5	6	7

Please rate the degree to which you agree or disagree with the following statements.

Since seeing *Tales of the Maya Skies*, I...	Strongly Disagree						Strongly Agree
Felt more interested in astronomy.							
Felt more interested in Maya culture.							
Have noticed things that remind me about the Maya more often in everyday life.	1	2	3	4	5	6	7
Have paid more attention to things that remind me about the Maya topics when I've come across them in everyday life.	1	2	3	4	5	6	7
Actively sought more information about the Maya (looking it up online, in a book or magazine, asking someone).	1	2	3	4	5	6	7
Went to a museum to learn more about the Maya.	1	2	3	4	5	6	7
Went to a museum to learn more about astronomy.	1	2	3	4	5	6	7
Saw another planetarium show.	1	2	3	4	5	6	7
Had more unanswered questions about the Maya or astronomy.	1	2	3	4	5	6	7

Appendix B: Study 2 Instruments

Pre-Show Questionnaire

Please circle the number that best reflects your interest in and your knowledge about following topics in a planetarium show.

Your interest None A lot		**Your knowledge** None A lot
1 2 3 4 5 6 7	**Mayan astronomy:** use of observation of the night sky to develop a calendar and plan an agricultural system.	1 2 3 4 5 6 7
1 2 3 4 5 6 7	**Ancient Mayan culture:** religious/spiritual beliefs, social structures, politics, and economics	1 2 3 4 5 6 7
1 2 3 4 5 6 7	**Daily life of the ancient Maya people:** foods, lifestyle, customs, celebrations, and other traditional practices of everyday people	1 2 3 4 5 6 7
1 2 3 4 5 6 7	**Present-day Mayan culture:** their connection to ancient Maya, where and how they are currently living today	1 2 3 4 5 6 7

Where did the ancient Maya live (in today's terms)?

- □ Peru, Bolivia, Colombia
- □ Australia, New Zealand, Tasmania
- □ Arizona, New Mexico, Utah
- □ Thailand, Vietnam, Cambodia
- □ Mexico, Belize, Guatemala

When approximately was the height of the ancient Mayan culture?

- □ 2000 to 1700 BC
- □ 1000 to 700 BC
- □ 600 to 900 AD
- □ 1500 to 1800 AD

How did the ancient Maya live?

- □ Mostly on farms, near small cultural town centers
- □ Small, family subsistence farms
- □ Nomadic tribes roaming the countryside
- □ Large cities with farms around them
- □ Floating coastal cities

What are the Maya known for? (Check all that apply)

- □ Defeated early European explorers in large battle
- □ Created a sophisticated calendar
- □ Developed skilled fishing techniques
- □ Astronomical knowledge
- □ Were early explorers of the seas
- □ Built large cities
- □ Invented explosives

What is the status of Maya today?

- □ The Maya still live in their original regions, but also elsewhere in the world.
- □ The Maya were extinguished by early European settlers in the 1500s.
- □ The Maya lived until about 1800, then vanished due to disease.
- □ The fate of the Maya is unknown today.

As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?

- □ Every day at noon
- □ Only on the first day of summer
- □ Only on the first day of winter
- □ On both the first days of spring and fall
- □ Never from your current location

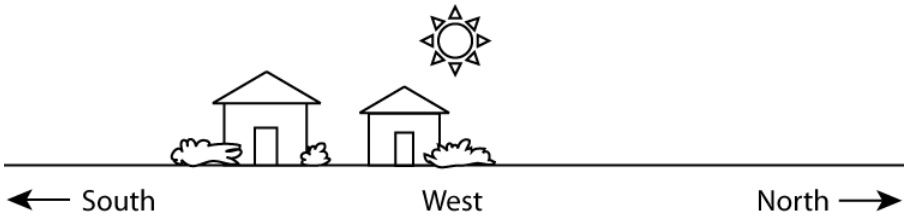
When the Moon appears to completely cover the Sun (a Solar Eclipse), the Moon must be at which phase?

- □ Full
- □ New
- □ First Quarter
- □ Last Quarter
- □ At no particular phase

Where does the Sun's energy come from?

- □ Nuclear fusion:
  The combining of light elements into heavier elements
- □ Nuclear fission:
  The breaking apart of heavy elements into lighter ones
- □ Thermal heating:
  The glow from molten rocks
- □ Ambient heating:
  Heat left over from the Big Bang

On September 22nd, in North America, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?



- □ Farther south
- □ In the same place
- □ Farther north

Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

- □ North Star, Moon, Sun, Venus
- □ Sun, Moon, Venus, North Star
- □ Moon, Sun, Venus, North Star
- □ Moon, Sun, North Star, Venus
- □ Moon, Venus, Sun, North Star

Please tell us about yourself:

Have you ever seen a planetarium show before?

□ Yes □ No □ Not Sure

Have you ever seen *Tales of Maya Skies* before?

□ Yes □ No □ Not Sure

Have you ever visited Chabot Space & Science Center before today?

□ Yes □ No □ Not Sure

Are you male or female?

□ Male □ Female

What year were you born? (ex. 1975): __ __ __ __ __ __ __

What ethnicity would you describe yourself as? (Check as many as apply)

- □ Asian American or Pacific Islander
- □ Black or African American
- □ Latino or Hispanic
- □ Native American or indigenous
- □ Maya
- □ Nahuatl or other Latin American indigenous group
- □ White or Caucasian
- □ Other/mixed (please describe) _____

What is the highest level of formal education you have completed?
(Check one)

- □ Elementary or middle school
- □ Some high school
- □ High school diploma or equivalent
- □ Community college or some college
- □ Bachelor's degree
- □ Some graduate school
- □ Graduate degree
- □ Technical school

THANK YOU!

Immediate-Post Questionnaire

For each pair of adjectives below, check the box that represents how you would describe *Tales of the Maya Skies*. The closer a box is to a word, the more strongly you think that word describes the show.

Overall, how would you describe *Tales of the Maya Skies*?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Objective (fact-based)	☐	☐	☐	☐	☐	☐	Subjective (opinion-based)
Stimulating	☐	☐	☐	☐	☐	☐	Dull

How would you describe <u>the visuals</u> in the show?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Supported the story	☐	☐	☐	☐	☐	☐	Distracted from the story
Complicated	☐	☐	☐	☐	☐	☐	Simple

Please rate the degree to which *Tales of the Maya Skies* made you feel the following things:

While I was watching *Tales of the Maya* Skies, I felt…

	Not at all						Completely
I was surrounded by images and sound.	1	2	3	4	5	6	7
I was in the middle of the experience.	1	2	3	4	5	6	7
I was watching a program.	1	2	3	4	5	6	7
I was in a program.	1	2	3	4	5	6	7
I was transported to a different place.	1	2	3	4	5	6	7
My body was here but my senses were taken somewhere different.	1	2	3	4	5	6	7
I was visiting a different place and time.	1	2	3	4	5	6	7

List three main ideas that you learned about the stars, sun, and planets from watching *Tales of the Maya Skies*.

4. _____

5. _____

6. _____

Please tell us about three key ways that the Maya used knowledge about astronomy in their daily lives.

4. _____

5. _____

6. _____

What did the story of *Tales of the Maya Skies* communicate to you?

Please rate the extent to which you felt the show effectively communicated each of the following:

	Not at all						Completely
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	1	2	3	4	5	6	7
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	1	2	3	4	5	6	7
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	1	2	3	4	5	6	7
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	1	2	3	4	5	6	7
By observing the patterns of the sun, moon and planets, the Maya created a precise, accurate calendar that marked the seasons.	1	2	3	4	5	6	7
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	1	2	3	4	5	6	7
Corn was so important to the Maya that it played a strong role in origin stories.	1	2	3	4	5	6	7
The night sky represents the origin story of the Maya.	1	2	3	4	5	6	7

Below are four story descriptions that may or may not represent the story that was told in *Tales of the Maya Skies*. Please tell us how much the show told each of these stories:

From a pool of 100 points, assign each story description a point-value based on how well you thought it describes the story that was told in *Tales of the Maya Skies*. A high point-value means it told that story a great deal; a point-value of 0 means it did not tell that story at all. The total points you assign should equal 100.

So, if you thought *Tales of the Maya Skies* told these four stories equally well, you would give each one 25 points. If you thought that *Tales of the Maya Skies* told only one of these stories, you would give that one 100 points, and the others 0 points.

_____ A story about the Maya and their culture, including their knowledge and use of astronomy.

_____ A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society.

_____ A story of Maya folklore and mythology and how that relates to Maya culture.

_____ A story about astronomical concepts and how the Maya learned these concepts.

_____ Total Points (should equal 100)

Please rate how much you liked each of these elements of the story of *Tales of the Maya Skies*.

Did you like this about the show?

	Not at all						Completely
A story about the Maya and their culture, including their knowledge and use of astronomy.	1	2	3	4	5	6	7
A story about the Maya's knowledge of the science of astronomy, and how this was important to Maya society.	1	2	3	4	5	6	7
A story of Maya folklore and mythology and how that relates to Maya culture.	1	2	3	4	5	6	7
A story about astronomical concepts and how the Maya learned these concepts.	1	2	3	4	5	6	7

Can we contact you in a month or two to find out what you think about your planetarium experience? We will not use your contact information for any other purpose.

☐ Yes ☐ No
First Name: _____

Email: _____
and/or
Phone number: _____

THANK YOU!

Delayed-Post Questionnaire

List the main ideas that you learned about the stars, sun, and planets from watching *Tales of the Maya Skies*:

What are the key ways that the Maya used knowledge about astronomy in their daily lives?

What did the story of *Tales of the Maya Skies* communicate to you?

Please rate the extent to which you felt the show effectively communicated each of the following:

	Not at all						Completely
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	1	2	3	4	5	6	7
Observing the heavens in order to understand the movement of planets and the apparent movement of the sun became embedded into Maya culture, religion, and agriculture.	1	2	3	4	5	6	7
Cycles of nature and astronomy were recorded by the Maya to become part of an accurate calendar system including the alignment of important buildings.	1	2	3	4	5	6	7
Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	1	2	3	4	5	6	7
By observing the patterns of the sun, moon and planets, the Maya created a precise, accurate calendar that marked the seasons.	1	2	3	4	5	6	7
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	1	2	3	4	5	6	7
Corn was so important to the Maya that it played a strong role in origin stories.	1	2	3	4	5	6	7
The night sky represents the origin story of the Maya.	1	2	3	4	5	6	7

THANK YOU!

Appendix C: Study 3 Instruments

Pre-Show Questionnaire

Where did the ancient Maya live (in today's terms)?

- □ Peru, Bolivia, Colombia
- □ Australia, New Zealand, Tasmania
- □ Arizona, New Mexico, Utah
- □ Thailand, Vietnam, Cambodia
- □ Mexico, Belize, Guatemala

When approximately was the height of the ancient Mayan culture?

- □ 2000 to 1700 BC
- □ 1000 to 700 BC
- □ 600 to 900 AD
- □ 1500 to 1800 AD

How did the ancient Maya live?

- □ Mostly on farms, near small cultural town centers
- □ Small, family subsistence farms
- □ Nomadic tribes roaming the countryside
- □ Large cities with farms around them
- □ Floating coastal cities

What are the Maya known for? (Check all that apply)

- □ Defeated early European explorers in large battle
- □ Created a sophisticated calendar
- □ Developed skilled fishing techniques
- □ Astronomical knowledge
- □ Were early explorers of the seas
- □ Built large cities
- □ Invented explosives

What is the status of Maya today?

- □ The Maya still live in their original regions, but also elsewhere in the world.
- □ The Maya were extinguished by early European settlers in the 1500s.
- □ The Maya lived until about 1800, then vanished due to disease.
- □ The fate of the Maya is unknown today.

As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?

- □ Every day at noon
- □ Only on the first day of summer
- □ Only on the first day of winter
- □ On both the first days of spring and fall
- □ Never from your current location

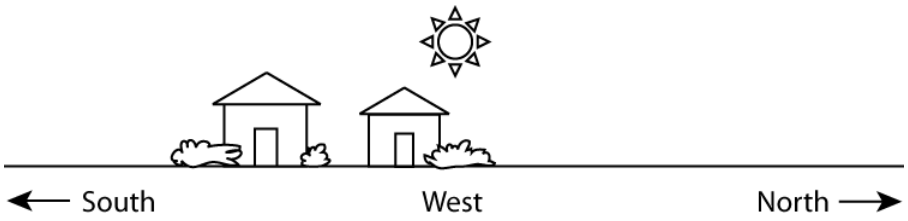
When the Moon appears to completely cover the Sun (a Solar Eclipse), the Moon must be at which phase?

- □ Full
- □ New
- □ First Quarter
- □ Last Quarter
- □ At no particular phase

Where does the Sun's energy come from?

- □ Nuclear fusion:
  The combining of light elements into heavier elements
- □ Nuclear fission:
  The breaking apart of heavy elements into lighter ones
- □ Thermal heating:
  The glow from molten rocks
- □ Ambient heating:
  Heat left over from the Big Bang

On September 22nd, in North America, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?



- □ Farther south
- □ In the same place
- □ Farther north

Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

- □ North Star, Moon, Sun, Venus
- □ Sun, Moon, Venus, North Star
- □ Moon, Sun, Venus, North Star
- □ Moon, Sun, North Star, Venus
- □ Moon, Venus, Sun, North Star

Please tell us about yourself:

Have you ever seen a planetarium show before?

□ Yes □ No □ Not Sure

Have you ever seen *Tales of Maya Skies* before?

□ Yes □ No □ Not Sure

Have you ever visited Chabot Space & Science Center before today?

□ Yes □ No □ Not Sure

Are you male or female?

□ Male □ Female

What year were you born? (ex. 1975): __ __ __ __ __ __ __ __

What ethnicity would you describe yourself as? (Check as many as apply)

- □ Asian American or Pacific Islander
- □ Black or African American
- □ Latino or Hispanic
- □ Native American or indigenous
- □ Maya
- □ Nahuatl or other Latin American indigenous group
- □ White or Caucasian
- □ Other/mixed (please describe) _____

What is the highest level of formal education you have completed? (Check one)

- □ Elementary or middle school
- □ Some high school
- □ High school diploma or equivalent
- □ Community college or some college
- □ Bachelor's degree
- □ Some graduate school
- □ Graduate degree
- □ Technical school

THANK YOU!

Immediate-Post Questionnaire

For each pair of adjectives below, check the box that represents how you would describe *Tales of the Maya Skies*. The closer a box is to a word, the more strongly you think that word describes the show.

Overall, how would you describe *Tales of the Maya Skies*?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Objective (fact-based)	☐	☐	☐	☐	☐	☐	Subjective (opinion-based)
Stimulating	☐	☐	☐	☐	☐	☐	Dull

How would you describe <u>the visuals</u> in the show?

Good	☐	☐	☐	☐	☐	☐	Bad
Boring	☐	☐	☐	☐	☐	☐	Entertaining
Informative	☐	☐	☐	☐	☐	☐	Not informative
Incomprehensible	☐	☐	☐	☐	☐	☐	Comprehensible
Supported the story	☐	☐	☐	☐	☐	☐	Distracted from the story
Complicated	☐	☐	☐	☐	☐	☐	Simple

Please rate the degree to which *Tales of the Maya Skies* made you feel the following things:

While I was watching *Tales of the Maya* Skies, I felt…

	Not at all						Completely
I was surrounded by images and sound.	1	2	3	4	5	6	7
I was in the middle of the experience.	1	2	3	4	5	6	7
I was watching a program.	1	2	3	4	5	6	7
I was in a program.	1	2	3	4	5	6	7
I was transported to a different place.	1	2	3	4	5	6	7
My body was here but my senses were taken somewhere different.	1	2	3	4	5	6	7
I was visiting a different place and time.	1	2	3	4	5	6	7

List three main ideas that you learned about the stars, sun, and planets from watching *Tales of the Maya Skies*.

7. _____

8. _____

9. _____

Please tell us about three key ways that the Maya used knowledge about astronomy in their daily lives.

7. _____

8. _____

9. _____

What did the story of *Tales of the Maya Skies* communicate to you?

Please rate the extent to which you felt the show effectively communicated each of the following:

	Not at all						Completely
Maya culture, life, cities, and architecture are built upon the Maya's understanding of astronomy.	1	2	3	4	5	6	7
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Mayan stories, traditions, and architecture illustrate what the Maya knew about astronomy's role in Mayan daily life.	1	2	3	4	5	6	7
By observing the patterns of the sun, moon and planets, the Maya created a precise, accurate calendar that marked the seasons.	1	2	3	4	5	6	7
By observing patterns of Venus, the Maya could predict rainy seasons in order to plan for agriculture.	1	2	3	4	5	6	7
Corn was so important to the Maya that it played a strong role in origin stories.	1	2	3	4	5	6	7
The night sky represents the origin story of the Maya.	1	2	3	4	5	6	7

THANK YOU!