Informal Science Education at Science City

by

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Abstract

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University of Kansas, April 2007

The presentation of chemistry within informal learning environments, specifically science museums and science centers is very sparse. This work examines learning in Kansas City's Science City's *Astronaut Training Center* in order to identify specific behaviors associated with visitors' perception of learning and their attitudes toward space and science to develop an effective chemistry exhibit. Grounded in social-constructivism and the Contextual Model of Learning, this work approaches learning in informal environments as resulting from social interactions constructed over time from interaction between visitors. Visitors to the *Astronaut Training Center* were surveyed both during their visit and a year after the visit to establish their perceptions of behavior within the exhibit and attitudes toward space and science. Observations of visitor behavior and a survey of the Science City staff were used to corroborate visitor responses. Eighty-six percent of visitors to Science City indicated they had learned from their experiences in the *Astronaut Training Center*. No correlation was found between this perception of learning and visitor's interactions with exhibit stations. Visitor attitudes were generally positive toward learning in informal settings and space science as it was presented in the exhibit. Visitors also felt positively toward using video game technology as learning tools. This opens opportunities to developing chemistry exhibits using video technology to lessen the waste stream produced by a full scale chemistry exhibit.

Acknowledgements

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Table of Contents

List of Figures

page

List of Tables

List of Schemes

Chapter 1

Introduction

Development of life-long learners is fast becoming an emphasis within the educational community. K-12 schools, colleges, and universities no longer have a monopoly on educational programs, as libraries, museums, after-school programs (McLeod & Kilpatrick, 2001), and even theme parks (Petkewich, 2006) are stepping into the arena to develop material to encourage students of all ages to learn more about math and science. Due to the increase in direct competition from other leisure-time activities, science centers are focusing more on the educational value they offer the public. As a consequence, museums are evaluating the most salient aspects of exhibits and/or identifying the hallmarks of learning in their exhibits to evaluate exhibit effectiveness and document visitor learning (Birney, 1988; Feher & Rice, 1988; Henderson & Watts, 2000; Livingstone, Pedretti, & Soren, 2001; Marek, Boram, Laubach, & Gerber, 2002; Minneapolis Institute of Arts, 1998; Paris, Troop, Henderlong, & Sulfaro, 1994; Stevens & Hall, 1997; Trautmann, Ingraffea, & Krafft, 2002). This research examines the *Astronaut Training Center* at Kansas City's Science City to explore aspects of an effective exhibit in terms of the visitors' perception of learning and their attitudes toward science and uses these findings to inform the development of a chemistry exhibit.

Background

The need for a technologically adept workforce is growing with the use of computers, cell phones, and e-mail to conduct business across the world. As the influence of science and technology in our daily lives grows, the importance of understanding both science as an enterprise and a phenomenon and how scientists think and view the world increases (American Association for the Advancement of Science, 1993). The *Benchmarks for Science Literacy*, developed under Project 2061 to identify how students should progress in understanding science, seeks to develop critical thinking skills, understanding the application of science and technology, and general knowledge through public education methods (formal schooling, and free-choice education facilities) *(American Association for the Advancement of Science, 1993)*. Instead of providing educators with a list of specific requirements, the *Benchmarks* encourage using inquiry-based methods to teach science. Scientific topics covered by the *Benchmarks* include the nature of science and our surroundings in the universe. To achieve the goals set by the *Benchmarks*, formal and informal education facilities need to work together to provide the student, at any level of education, a more robust picture of the nature of science (Hofstein, Bybee, & Legro, 1997).

What is informal science education?

Historically, the terms *formal* and *informal* have been used to differentiate between compulsory and voluntary learning (Figure 1.1). Formal education encompasses colleges and universities, community colleges, and the pre-K-12 school system and is generally seen as the main source of knowledge growth within an individual (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Marsick & Watkins, 2001). Informal education, also called *free-choice education*, refers to any educational facility that is not part of the compulsory educational system

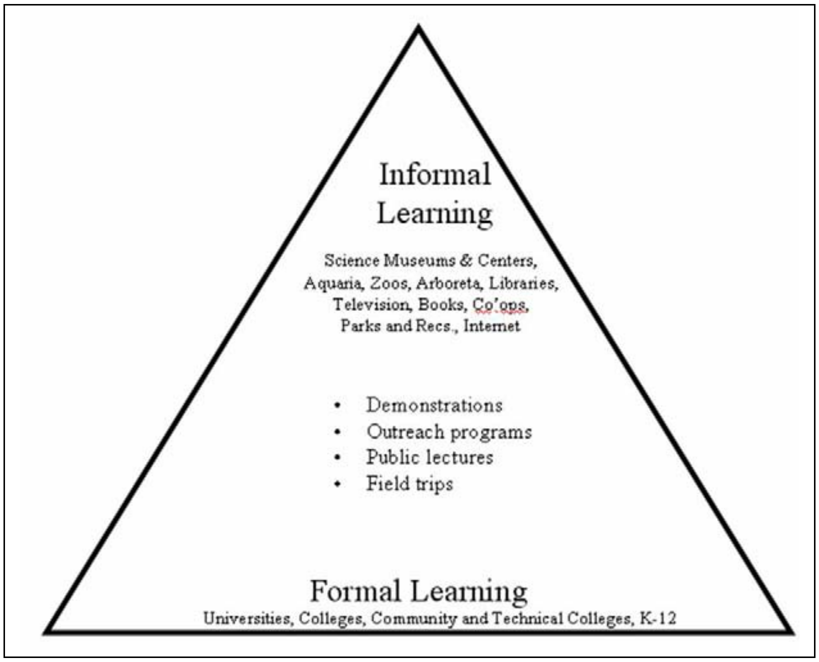


Figure 1.1: Overlap of Formal and Informal Education

(A. Anderson, Druger, James, Katz, & Erniesse, 2001; Falk, 2001a, p. 6). This encompasses museums, science centers, community organizations, aquaria, zoos, botanical gardens, as well as television and print media. Traditional views of the learning environments place formal and informal learning education facilities on a non-overlapping continuum, though both use similar teaching methods. Both have their own strengths and weaknesses. Formal education allows students to learn content in depth, as presented to them by teachers who have mastered the content themselves, or professors who have devoted their career to studying specific phenomenon. As valuable as this in-depth knowledge is, an awareness that a phenomenon occurs is just as valuable for the general public (Wellington, 1990). Informal learning experiences offer students of all ages the opportunity to participate in programs not typically available in the formal learning context and for facilitators to show the enthusiasm they have for the science they love.

In contrast to formal education, informal education offers more freedom of choice to learn about material presented. Falk and Dierking argue that the learning process which occurs in both types of educational environments does not change, as is suggested by pairing the modifiers *formal* and *informal* with *learning*, but only the choice of when and how a person will acquire knowledge (Falk, 2001a). As such, they coined *free-choice learning* as a term "that recognizes the unique characteristics of such learning: free-choice, non-sequential, self-paced, and voluntary" (Falk, 2001a, p. 7). While the term free-choice learning encompasses much of the learning environment, the preferred term in literature is still informal, so this term will be used through this work.

Informal science education, therefore, focuses on learning about science, technology, engineering, and mathematics (STEM) experiences within the voluntary and self-directed environment provided in informal learning facilities (National Science Foundation Division of Elementary, 2006). The National Science Foundation views these experiences as "designed to increase interest, engagement, and understanding of STEM by individuals of all ages and backgrounds" (Education and Human Resources (EHR), 2005). Science in these environments is no longer represented stereotypically as a scientist lecturing to a class, talking about isolated phenomena. Instead, science is presented to the public within its context, as a social process of examining the physical world to be aware of and understand its processes.

What are interactive science centers?

Interactive science centers provide opportunities for the public to interact as a community with scientific phenomena as they occur in the natural world. The Association for Science and Technology Centers (ASTC) views the purpose of sciences centers as providing a way for people to connect with science, through firsthand experiences designed to encourage and inspire curiosity (Association of Science and Technology Centers, 2006). Within science centers, people can interact with giant levers, wave tanks, etc., see science demonstrations and science films, participate in workshops, and take part in debates, to name a few of the many activities that occur.

The major difference between a science center and a science museum is the use of hands-on approaches to learning in science centers. Each exhibit is designed to be handled by people of all ages. Exhibits are also brightly colored and typically produce sounds along with motion to attract people with different learning styles. Very few exhibits are designed not to be played with. Even paintings on the walls may invite visitors to touch the panel or listen to an audio recording about the panel. Almost nothing is hands-off or quiet about these institutions. In contrast, science museums focus on displaying artifacts of technological progress and/or historical instruments used as part of scientific research by famous scientists. Very few exhibits in the museum lend themselves well to children handling pieces of the exhibit. Audio panels, if present, speak in hushed tones, adding to the atmosphere of strained silence.

Rationale for the Research

Based on its representation in the science museum literature, one would believe that chemistry has one of the lowest profiles among the scientific disciplines (see Chapter 2). The absence of chemistry in science museums and centers has been a major concern of the American Chemical Society (ACS) (Association of Science and Technology Centers, 2006; Breslow, 1997). In a project sponsored by the ACS POLYED committee, Collard and McKee surveyed ASTC science museums about how polymer chemistry is presented in their institutions (Collard & McKee, 1998). The researchers found that the use of polymer chemistry to teach chemistry within the science center was not reflective of the wide influence of polymers in biological, technological, and scientific applications. While respondents (ASTC members, science museum or center curators and staff) could identify polymers used in the exhibit, the exhibits did not discuss the importance of polymer chemistry to everyday life. Collard describes some exhibits as having molecular models of DNA or proteins, but not referencing or displaying synthetic polymers. A separate study conducted by ASTC identified many obstacles to developing new exhibits related to chemistry: difficulty illustrating "wet" chemistry, the absence of chemistry professionals in the museum studies field, and few readily accessible resources, including staff with training in chemistry (Templeton, 1992). To address the lack of enthusiasm by the general public and the lack of quality chemistry exhibits in science centers, the Center for Environmentally Beneficial Catalysis intends to develop an exhibit that addresses these concerns and explains the importance of environmental and/or green chemistry.

This study examines a popular exhibit at Science City located in Union Station, Kansas City, MO in order to identify aspects of the exhibit that visitors perceive to be sources of learning. Based on the research, this study also proposes three exhibit ideas related to environmental and/or green chemistry and its impact on society to provide additional exhibits to increase the research literature on chemistry within science museums.

Purpose of the Research

The purpose of this research is to examine how visitors to a science center with a unified exhibit theme respond to the material being presented in terms of their attitude toward the content and their perception of learning. Specifically, this research addresses the following questions:

- Do visitors recognize they are learning from interactions with the exhibits?
- If so, what do they think they are learning?
- How can we use our knowledge of museum learning and data from this research to develop an exhibit that communicates concepts related to environmental and/or green chemistry?

To address these questions, three studies were conducted to look at visitors' perception of learning and attitude toward science over time. A fourth study examined how visitors behaved during their visit based on observations.

Study 1: Investigation of visitors' perception of experiences and attitudes toward space, astronauts, and science during their visit to the *Astronaut Training Center* in Science City.

Study 2: Investigation of visitors' change in perception of experiences and attitude toward space, astronauts, and science after their visit to Science City's *Astronaut Training Center*.

Study 3: Investigation of Science City facilitators' and educational staff's attitudes toward science and space and perceptions of visitors' interaction within the *Astronaut Training Center* exhibit.

Study 4: Observations of visitor behavior to examine the validity of visitors' self-reported usage on the visitor surveys.

Structure of the Thesis

This thesis is composed of four studies and their implications on the development of three possible environmental and/or green chemistry exhibits for use at science museums and/or centers. Each study is guided by the same basic research questions, summarized in Tables 1.1 through 1.4: Do visitors learn? What do they perceive they learned? What attitudes do they hold with respect to exhibit content and science, and how do these perceptions and attitudes change over time?

Study 1: Initial Visitor Survey

The first study investigates visitors' perceptions of their experiences at Science City and their attitudes toward the subject matter of the exhibit: space, science, and astronauts (Table 1.1). This study lays the groundwork for identifying aspects of the exhibits that are salient to visitors' perceptions and identifies aspects for inclusion in the follow-up study.

Table 1.1: Research Purpose and Methods of Study 1: Initial Visitor Survey

Purpose of Study	Research Questions	Methods
Investigation of visitors' perception of experiences and attitudes toward space, astronauts, and science during their visit to the *Astronaut Training Center* in Science City.	1. Do visitors perceive they are learning from the *Astronaut Training Center*? 2. What attitudes toward science do visitors to Science City hold? 3. Is there a correlation between perceived learning and the sample's demographics?	Survey questions • Self-report exhibit usage • Self-report attitude items • Open-ended, descriptive questions • Self-report demographic data

Study 2: Follow-up Visitor Study

The second study follows up on the initial visitor survey to explore changes in visitors' perceptions of their experiences in the *Astronaut Training Center* and their attitudes toward astronauts, space, and science, over time (Table 1.2). The follow-up survey also provided an opportunity to explore how the use of video technology can affect visitors' perception of learning in this environment. The purpose of this study was to capture the long-term influence of the informal learning experiences gained at Science City.

Table 1.2: Research Purpose and Methods of Study 2: Follow-up Visitor Study

Purpose of Study	Research Questions	Methods
Investigation of visitors' change in perception of experiences and attitude toward space, astronauts, and science after their visit to Science City's *Astronaut Training Center*.	1. Does visitors' perception of their experiences change over time? 2. Do visitors' attitudes toward science improve over time? 3. Does the use of multimedia technology effect visitors' perception of learning?	Survey questions • Self-report exhibit usage • Self-report attitude items • Open-ended, descriptive questions

Study 3: Educational Staff Survey

The educational staff survey examines the facilitators at Science City to determine their perception of visitors' interaction with the exhibit and their personal attitudes toward science (Table 1.3). This study examines how the facilitators view their role in visitors' learning experiences and was designed to gain a different perspective on visitors' behaviors within the exhibit. Facilitators' understanding of the nature of science and the purpose of the exhibit was also determined.

Table 1.3: Research Purpose and Methods of Study 3: Educational Staff Survey

Purpose of Study	Research Questions	Methods
Investigation of Science City facilitators' or educational staff's perception of visitors' interaction with the *Astronaut Training Center* exhibit and the staff members' attitudes toward science and space.	1. How much does the educational staff feel the visitors are interacting with the exhibit? 2. What attitudes does the staff have toward the ATC exhibit? 3. How does the staff understand the nature of science?	Survey questions • Report of visitor usage • Attitude about visitors experiences • Open-ended: Nature of Science

Study 4: Behavior Analysis

The behavior analysis examines what visitors choose to do or not do while in the *Astronaut Training Center* exhibit. Visitors were observed during their visit and their behavior recorded on a rubric. This study was designed to gain further insight into which exhibits were more popular with adults and children, and how visitors interacted with the exhibit stations. This study was meant to verify the accuracy of the self-report data within the initial and follow-up visitor survey.

Table 1.4: Research Purpose and Methods of Study 4: Visitor Behavior Analysis

Purpose of Study	Research Questions	Methods
Investigation of visitor behavior within the exhibit.	1. How frequently do visitors manipulate each exhibit station? 2. Who manipulates each station the most? 3. Do visitors talk about the exhibit?	Observation of visitors via rubric • Behavior • Socialization • Interaction

The remaining chapters (4-7) examine the relationships between the four studies and apply this knowledge to three potential exhibits relating to environmental and/or green chemistry. Chapter Two examines the literature with regard to the public's understanding of science and chemistry, chemistry exhibits in science museums and science centers, and theories of learning to explore the long-term impact of learning in science museums. Chapter Three describes the methodology used in the studies. Chapters Four through Seven examine the results of the four studies and relationships found amongst the surveys. Chapter Eight analyzes what was learned from the study and proposes three environmental chemistry exhibits based on the knowledge gained in this research. Finally, Chapter Nine provides a summary of this work and proposes areas for future work.

Chapter 2

Conceptualizing Science Museum Learning

Science Literacy and the Public's Understanding of Science

In a world dominated by science and technology, citizens need to understand the nature of science to make informed decisions regarding the use of knowledge produced by this endeavor. The need for science literacy among U.S. citizens is being addressed by the American Association for the Advancement of Science's (AAAS) Project 2061 with the premise that all students can do science. To be scientifically literate, a person

> … is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes.
>
> … Without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems (Rutherford & Ahlgren, 1990).

Currently, the methods of instruction and textbooks used in science courses focus on reading, recitation, memorizing answers, and learning bits and pieces of information, instead of developing arguments, doing experiments, exploring questions, developing critical thought and understanding in context (Shen, 1975), the basis of modern science.

Underlying these ideas is the assumption that science can be translated from the technical language of science into ordinary public discourse. To do so, Shen

(1975) divided scientific discourse into three areas of focus for public interest: practical, cultural, and civic. *Practical scientific literacy* focuses on understanding of scientific disciplines to raise an individual's standard of living. This type of literacy includes areas such as health, nutrition, and modern agriculture and involves an individual having an understanding of science in order to solve practical problems. *Cultural science literacy* is motivated by intrinsic curiosity, an individual's desire to know. Science is viewed in this case as a major human achievement, akin to how art appreciation is to art. *Civic scientific literacy* focuses on understanding science in order to actively participate in public debate about scientific issues and understand science as it is presented in newspapers. Civic scientific literacy is needed by an individual in order to lobby their legislator in an informed manner about how to write laws regarding the production and use of scientific knowledge. Miller (1998) includes within this definition *understanding of scientific terminology*, the process or nature of scientific inquiry, and some level of understanding of the impact of science and technology on society. While Shamos (1995) agrees on the importance of consumer scientific literacy, he argues that only true scientific literacy should be reserved for trained scientists.

All three types of scientific literacy can be addressed within science museums and centers. Exhibits, such as those on nutrition and agriculture at the Omniplex in Oklahoma City, focus on educating the public on modern agriculture and the basics of nutrition, addressing the practical side of science (Omniplex Science Museum, 2006). *Marvelous Molecules – The Secret of Life,* and *Realm of the Atom* at the New York

Hall of Science help visitors explore the microscopic world, a lesson in civic scientific literacy that can follow visitors throughout their lives (New York Hall of Science, 2006). Shen's argument for the "planned proliferation of good 'ordinary-language science'" (p. 51) opens the door to science centers' mission of providing the public with opportunities to interact with science at a non-expert level (Persson, 2000).

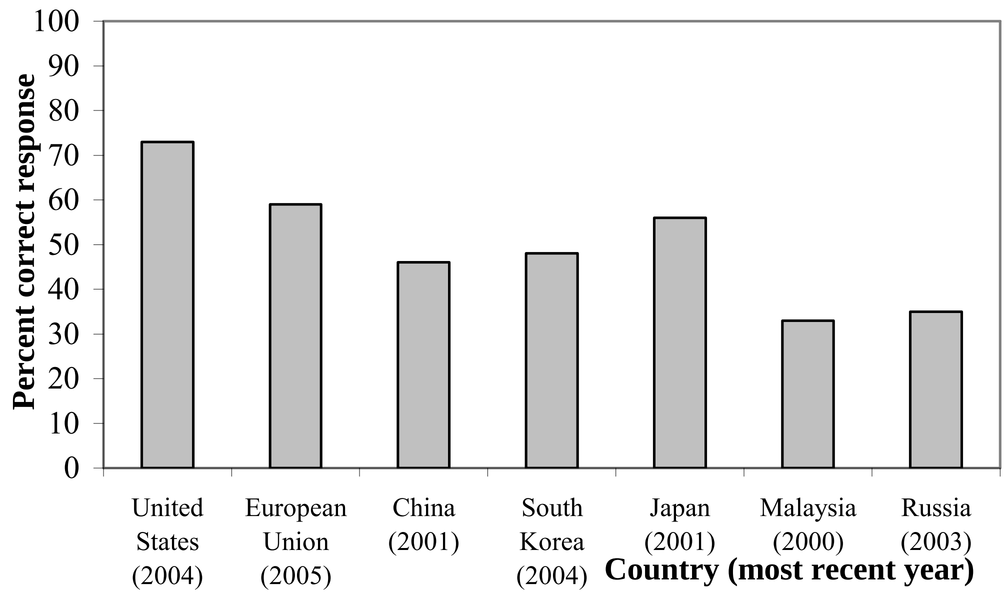
Lucas (1983), however, argues that science centers have not made a direct contribution to individual's scientific literacy in any of the three areas defined by Shen (1975). While science centers offer opportunities for visitors to learn, the attracting and holding power of these exhibits (typically 30 to 40 seconds) is not substantial enough to result in adequate levels of learning from interacting with the exhibit. The attractiveness and holding power of an exhibit then leads to interactions within the museum lasting two hour per visit on average (Falk, 1982b). In regard to button pushing, an easy physical manipulation used on many exhibits, Lucas cites Oppenheimer's comment that "frequently people walked off leaving the display to go through its paces unattended." As a result, a study by Borun (1977) found a negative correlation between the instructional power of an exhibit and the number of interactive devices, particularly among those with push-buttons, such that as the number of interactive devices increased, the amount of instruction was decreasing. Not only do some science museums offer limited instruction, but research also shows that visitors to science museums are from a narrow audience, family groups that are middle class, suburban and white (Falk, 1998). So while having the potential to address the public's understanding of science, science museums and science centers offer only a limited learning opportunity to a very limited audience, instead of reaching out to the people who need to scientific knowledge the most.

The Public's Science Literacy

The 2006 Science and Engineering Indicators, a report issued by the National Science Board for NSF, found that Americans generally have high levels of interest in science and technology (47% responded that they were very interested and 45% moderately interested in new scientific discoveries), but most are not very well informed about these subjects (52% moderately well informed and 32% poorly informed about new scientific discoveries) (National Science Board, 2006). Space exploration fared the worst of areas surveyed with 26% responding they were very interested and 47% moderately interested in the subject. Forty-three percent felt they were moderately well informed about space exploration, while another 43% felt they were poorly informed. Television was cited as the main source for these individuals' current news (51%), but dropped to 41% when the source was related to information about science and technology. Newspapers dropped from 22% for current news to 14% on science and technology. The Internet gained from 12% for current news to 18% on science and technology. Science museums were not listed as a leading source of science and technology information.

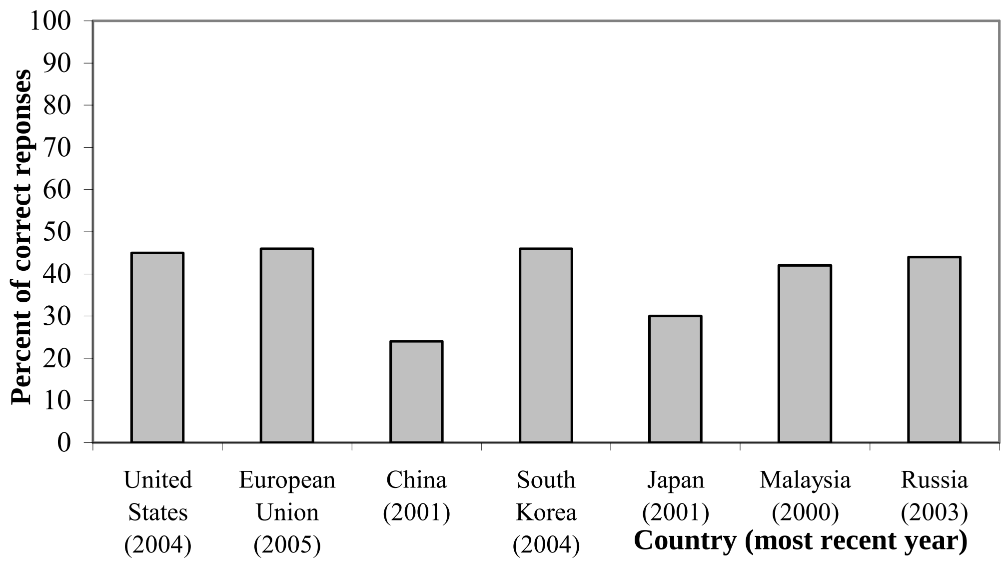
When looking at the types of establishments respondents visited, public libraries were the most frequent (75% of respondents had visited in the last 12 months) in the U.S., with zoos or aquariums (58%) and science and technology museums (30%) (National Science Board, 2006). Visits to science and technology museums were higher in the United States than in Europe (58% responded as having visited a science museum in the last 12 months, compared to 16%). Of those who did not attend a science museum or science center in Europe, 32% responded that they did not understand science and technology issues, while 31% responded that they did not care (European Commission, 2005). It is thought that despite the professed interest in science and technology in the U.S., interest in the U.S. is about the same as it is in Europe (National Science Board, 2006). Studies by the Pew Research Center for the People and the Press of top news items that attracted the public's interest found that very few of the news articles indicated as ones that readers followed were related to science and technology (Pew Research Center for the People and the Press, 2005). This illustrates the low level of interest the public has with respect to learning about science and chemistry outside of the requirements of the formal education system.

With respect to specific content knowledge held by the general public, the Science and Engineering Indicators specifically asked participants about their understanding of scientific knowledge. Two statements highlighted in the study focused on an individual's understanding of chemical knowledge: (1) "All radioactivity is man-made," and (2) "electrons are smaller than atoms" (Figures 2.1 and 2.2) (National Science Board, 2006) Compared to the other countries surveyed, the United States had the highest percentage of correct responses to the statement "all



Adapted from National Science Board's *Science and Engineering Indicators 2006.*

Figure 2.1: Percent of Correct Responses to the Statement "All radioactivity is man-made" World-wide



Adapted from National Science Board's *Science and Engineering Indicators 2006.*

Figure 2.2: Percent of Correct Responses to the Statement "Electrons are smaller than atoms" World-wide

radioactivity is man-made" (78%), but correct responses dropped to 45% when comparing the statement, "electrons are smaller than atoms," and below that of the European Union (46%) and South Korea (46%). Understanding the scientific process fared no better world wide, with only 43% of Americans and 37% of Europeans responding correctly to a question asking how an experiment is conducted, and 57% of Americans and 69% of Europeans indicating a correct understanding of the nature of probability.

Other gaps in the public's understanding of chemistry were identified as part of a front-end study by Wynne at the Oregon Museum of Science and Industry in Portland, OR (Wynne, 1997). Seventy-one percent of visitors surveyed said that chemistry is very important to life, but 69% responded that they only occasionally came into contact with chemicals. Clearly these visitors have a limited understanding of chemistry. Then, when shown an untitled copy of the Periodic Table, 50% of the respondents were able to identify it as the Periodic Table, while 21% responded "different chemicals", 6% "atoms", 2% "properties of elements", and 22% responded that they didn't know. A need for a better understanding of the nature of chemistry along with a practical understanding of its uses and common objects is present.

Historical View of Chemistry in Science Museums and Centers

The importance of educating the public on advances in the chemical profession has long been recognized by the American Chemical Society. Among the earliest issues of the *Journal of Chemical Education* (*JCE*) appear descriptions of lecture demonstrations being saved for student use in a museum (Baker, 1925), museums dedicated to famous chemists (Doyle, 1932; Krotikov, 1960; Scharrer, 1949; Sommer, 1931) and chemistry-related historical sites (McKee, Scott, & Young, 1934). Outside of *JCE*, the development of the Smithsonian Institute is indebted to the far thinking ability of a chemist, James Smithson, toward public science education (Smithsonian Institution Libraries, 1998).

McManus described the development of interactive science museums and science centers as growing out of the Cabinets of Curiosities which contained objects of interest to collectors and were housed in private homes (P. M. McManus, 1992). The first science museums developed from these private collections into natural history museums such as the British Museum in London, founded in 1753, and the Academy of Natural Sciences in Philadelphia, founded in 1812. These institutions had strong ties with academic disciplines in the universities as curators contributed to scientific knowledge and public education. Many of the displays were treated as ‘open storage’ to display objects in the research collections in a “three dimensional textbook” reflective of the curator’s current interests (P. M. McManus, 1992, p. 160).

Eventually, staff of these first generation science museums became increasingly unhappy with the lack of comprehensibility and enlightenment gained by the viewing public and the approach used to display objects changed. An off-shoot of the first generation science museums developed focused on scientific ideas and concepts, moving away from taxonomic arrangements. Displays began to follow Bloom's *Taxonomy of Educational Objectives* (Bloom, 1964). Museum evaluators began describing visitor behavior within the exhibitions to produce exhibits that catered to the consumer's learning objectives (P. M. McManus, 1992). Education was pushed to the forefront, through funding changes and professional development, while the museum's research function moved out of public view. Now, with these changes, science museums could boast that exhibition media were for the general public.

Growing out of these advancements into the public sector, the second generation of science museums was founded as public institutions whose purpose was to meet the needs of the growing industrial sector. Now, instead of displaying private collections to the masses, science museums began to focus on the applied science and industrial advances growing out of the Industrial Age (P. M. McManus, 1992). Many of these collections served as teaching aids to train a growing number of craftsmen and designers.

As the public became more interested in science through the successful but temporary public exhibitions and fairs between 1850 and World War II, the second stage of this generation of science museums developed (P. M. McManus, 1992). A mixture of entertainment and education, demonstrations and large pieces of machinery, these large science museums provided the public with access to scientific advances and technological progress. These museums retained the touchable and operational exhibits of technology museums as well as the research into the history of science components. The institutions relinquished their training element, and in its place, began performing mass public educational events with hands-on elements. The Science Museum, London, opening in 1928, was formed out of collections in the South Kensington Museum and the Patent Office Museum and was not intended to be historical in nature (Bud, 1997). While its predecessors did collect historical objects, the focus of this museum was on current technology. The opening of Children's Gallery in the 1930s and later Launchpad, cemented Science Museum's place in the second stage of the second generation, though other historical exhibits continued to open throughout Science Museum's history (Bud, 1997).

The third generation became less dependent on objects than its predecessors (P. M. McManus, 1992). Now concerned more with communicating scientific ideas and practice than with displaying objects or showing the history of science, the aim of these new science museums and science centers became public education, not scholarly research on its collections like its predecessors. While these venues offer many opportunities for informal research into intuitive ideas in science, the days of curators studying collections are gone. Exhibits are typically prepared by teams of specialists, evaluators, engineers, architects, designers, fabricators, and video producers and editors and emphasize the use of technology.

Like previous generations, two strands of exhibit design have developed from the third generation (P. M. McManus, 1992). The first focuses on non-object based thematic exhibitions, with interactive exhibits and typically concerned with larger concepts, like heredity, evolution, nutrition, ecology, and the human body. Examples include the New York Hall of Science (http://www.nyscience.org) and Lawrence Hall of Science (http://www.lawrencehallofscience.org). The second strand is the science center, with its decontextualized interactive exhibits. Examples include Launch Pad at the Science Museum, London (http://www.sciencemuseum.org.uk), the Exploratorium in San Francisco, CA (http://www.exploratorium.edu/), and the Omniplex Science Museum in Oklahoma City, OK (http://www.omniplex.org/). Science Centers of this generation are typically begun by enthusiastic educators, museum staff, scientists or engineers initially, as well as various local foundations.

Chemistry exhibits within these museums have developed along with the science museums. The earliest paper relating to museums in the *Journal of Chemical Education* belonged to R. A. Baker (1925), who argued for chemical reactions that can be presented in class and studied at leisure by students in a museum setting. This kind of facility was not intended for public use, more as a supplement for a laboratory component. C. A. Browne (1927) produced one of the earliest descriptions of a museum focusing on chemistry with the publication of a speech read during the golden jubilee celebration of the American Chemical Society and the dedication of a permanent memorial to Joseph Priestley's house in Northumberland, PA. After recounting the discoveries Priestley made in his home in Northumberland, Browne adds descriptions of the house and laboratory, which were preserved through donations of memorabilia collected by descendants of Doctor Priestley and others.

Objects on display include apparatus, letters, manuscripts, books, book plates, prints, portraits, and personal effects. Browne describes the museum as a place where visitors can "form a vivid conception of the personality and versatile genius of Joseph Priestley," implying the look-but-don't-touch nature of traditional museums. Today, the Priestly house is run by the Pennsylvania Historical and Museum Commission and is still open to public viewing (Pennsylvania Historical and Museum Commission, 2006).

Other descriptions of chemistry museums in the *Journal of Chemical Education* include the Leathersellers' Company's Technical College in London by Spiers in 1929, the chemical section of the Deutsches Museum by Prandtl in 1930, the Liebig Laboratory and Museum in Giessen, Germany by Sommer in 1931, Scharrer in 1949 and Sachtleben in 1957, the Chandler Chemical Museum at Columbia University by McKee, Scott, and Young in 1934, the Science Museum in South Kensington, London, by Greenaway in 1958 and again in 1964, and the Mendeleev Archives and Museum of Leningrad University by Krotikov in 1960. The articles typically describe exhibits of laboratories as they were used by the chemists they enshrine or how chemical laboratories have changed over time. None offer hands-on interactions for the visitors and few focused on the chemical concepts underlying the work done in those laboratories. The next appearance of an article relating to chemistry museums is an interview with Robert G. Anderson, the Director of the British Museum in 1995 by Wotiz.

The first study in the U.S. of the presentation of chemistry in science museums was done by A.M. Doyle at the U.S. National Museum in 1932. In it, she surveyed approximately 300 museums of science and history regarding the quality of presentation or intended presentation of chemistry within their institution. Of the 240 replies received, Doyle reports that "32 contained mineral collections and 85 described either few or extensive exhibits in chemistry. Some with no exhibits at present planned definitely for the future." Museums reporting to have chemistry exhibits at the time were: Cornell University's Baker Laboratory of Chemistry, Columbia University's Chandler Museum, New York Museum of Science and Industry, the Commercial Museum in Philadelphia, PA, the Department of Chemistry at the University of Pittsburgh, Pittsburgh, PA, and the Field Museum of Natural History in Chicago. Many, Doyle reports, happily sent along photographs of the exhibits for her personal inspection. Some report on the relationship between minerals on display and their chemical composition, though most boast of collections of specimens related to manufacturing and industrial processes and medicinal compounds which were to be used as visual aides at many universities. As Doyle points out "no subject is better adapted to experimental demonstration nor more in keeping with the spirit of the times, which demands to be 'shown.'"

Since these publications, little has been printed about chemistry in science museums and science centers. In 1984, an article by Worthy appeared in *Chemical and Engineering News* describing a new chemistry exhibit being added to Chicago's Science Museum. A description of this exhibit appeared in the *Journal of Chemical*

Education in 1986 by Ucko, Schreiner, and Shakhashiri. In contrast to previous descriptions of chemistry exhibits, the exhibit, *Everyday Chemistry*, incorporated demonstrations of chemical reactions, in place of the static displays previously presented. Visitors could push buttons to cause an exhibit to activate and the intended chemical reaction to occur. An example of one exhibit is the electrolysis of water ("Breaking Apart Water") where visitors, upon pushing a button to activate, can run a current through electrodes and decompose water. The formation of hydrogen and oxygen is shown in tubes placed side-by-side, containing polyethylene balls which float upward with the change in volume of gas. In the end, the hydrogen is combusted using a spark and a loud bang results as small amounts of water form on the inside of the container.

Twelve years later, the *Journal of Chemical Education* published an article on chemistry content in science museums. In that piece, Richard Zare, chair of the National Science Board commented on the growing number of members the Association of Science and Technology Centers (ASTC) and the lack of chemistry in exhibits at the museums he had visited (1996). The following year, Ronald Breslow spoke out as the ACS Immediate Past President in *Chemical and Engineering News* about the lack of chemistry in museums designed especially to develop enthusiasm for science in young children (1997). Both men point to the lack of permanent exhibits with live demonstrators as the main problem and agree that chemistry and museum professionals need to work together to develop more ideal chemistry exhibits. Both also called for using demonstrations that have already been developed, by adapting them to the museum setting.

A similar editorial appeared in *Chemistry in Britain* in 1977 (Greenaway, 1977). In this case, Frank Greenaway, then curator of the Science Museum in London, began by reminding readers that the last time an update of the chemistry galleries in the museum was described for members of the Royal Institute of Chemistry (which later merged into the Royal Society of Chemistry), *Chemistry in Britain* did not exist. (The publication began in 1965 and was replaced in 2004 by *Chemistry World*, after the merger of the two royal societies.) Greenaway implored chemists to see the need for updated and evolving chemistry displays within the Science Museum, due to its role in public education.

Other publications in this area focus on developing partnerships between local science centers and universities as a source for trained demonstrators and volunteer opportunities (Johnson, 1998; Payne et al., 2005; Silberman, Trautmann, & Merkel, 2004). Volunteers for the University of Wisconsin Internships in Public Science Education (UW IPSE) designed and implemented hands-on interactive activities in nanotechnology (Payne et al., 2005). In recent years, National Chemistry Week has also brought many chemists into the museum world for a few days to a week of activities with the public or through the development of public displays (Pacer, 1991).

Chemistry in Science Centers

Recent times have not brought science museums more chemistry exhibits. With the help of the American Chemical Society and the Camille and Henry Dreyfus Foundation, the Association of Science and Technology Centers (ASTC) surveyed its members in North America to determine the range, kind, and quantity of chemical science activities available in science centers (Templeton, 1992). Sixty-eight percent of the respondents reported having no substantial chemical-related exhibitions. Of those with some chemistry-related exhibits (28 museums), 40% reported the exhibit focused on physics or the physical basis of chemistry, 15% on biology or biochemistry, 14% on inorganic, 11% on organic, 7% on industrial, and 3% on historical chemistry. Forty-nine percent of the responding museums offered some chemistry activities for their visitors. Of resources available to museum staff, the majority reported being no better off than a high school.

Prior to the study conducted by ASTC, the Belmont Conference brought together 21 chemistry and science museum professionals from both ACS and ASTC to discuss issues in chemical literacy (Templeton, 1992). Participants identified four major obstacles facing science museums:

1. Creative resources have not been focused on the conceptual development and technical realization of interactive chemistry exhibitions. (i.e. wet chemistry is not the only chemistry)
2. Established museums have maintained and new museums have adapted existing chemistry programs more than they have developed new ones.
3. Communication between chemistry professionals and science museums has been carried out by only a small group of people.
4. Emphasis on chemistry by science museums is restricted by inadequate resources. (Templeton, 1992)

Participants felt that these obstacles would need to be overcome in order to recapture the public's enthusiasm toward science and chemistry that was lost during the turmoil that developed during the 1960s and 1970s when chemistry began to be associated with words like hazard, risk, and pollution. To foster the development and support of chemistry activities, participants in the conference outlined recommendations for science museums, funding sources, chemistry professionals, and ASTC's role for the future (Table 2.1).

In 1998, Collard and McKee surveyed 243 of the 355 ASTC members to evaluate the use of polymer chemistry in science museums (Collard & McKee, 1998). They found, that despite a high rate survey return (53%), similar to the ASTC survey, presentation of polymer chemistry was lacking. The National Plastics Center and Museum was the only respondent dedicated to the presentation of polymers. Collard and McKee identified the Museum of Science and Industry as having "one of the largest collections of *interactive* [stress in original] chemistry exhibits" with three displays of common polymeric items. The Smithsonian's Museum of American History in Washington, DC, includes two large exhibits with discussions of polymers. Collard and McKee follow that many polymer exhibits focus on physical properties rather than chemistry and that demonstrations are more prevalent than permanent exhibits.

Publications other than the *Journal of Chemical Education* are not without descriptions of modern chemistry exhibits. Rao and Roesky describe a chemistry museum encountered at the Göttingen University in Germany during a visit to the

Table 2.1: Belmont Conference Recommendations to Improve Chemical Education in Science Museums

For Science Museums

- Make a concentrated effort to increase the availability of high-quality chemistry exhibitions and programs
- Serve as test beds for chemistry communications
- Make chemistry an increased focus of science museum teacher support
- Help insure that chemistry careers are viable choices for all
- Locate funding for chemistry equipment, staff, and exhibition, and program development.

For Funding Sources

- Small-scale investments for program development
- Medium-scale investments for low-tech exhibitions that can be circulated
- Large-scale investments in experimentation with new exhibition approaches and techniques.

For Chemistry Professionals

- Learn more about local science museums and find ways to contribute
- Recommend corporate support
- Underwrite chemistry education programs and scholarship funds

ASTC's Role

- Disseminate information about chemical education activities
- Encourage traveling exhibitions on chemistry topics
- Seek out ways to strengthen ties with ACS and other chemistry organizations
- Encourage and promote partnerships between science museums and chemistry professionals

Adapted from: Templeton, M. *A Formula for Success: Chemistry at Science Museums*; Association of Science-Technology Centers: Belmont, Maryland, 1992.

university in *Current Science* (Rao & Roesky, 2001). Contained within the museum are memorabilia from some of the famous chemists that have been at the university, such as Max Born, Carl Friedrich Gauss, Werner Heisenberg, and Walther Nernst, including writings, letter correspondence, glassware, equipment and apparatus, prepared samples as well as photographs and family records. Allison (2002) described the museum, Catalyst: the Museum of the Chemical Industry, located in Widnes, Cheshire, U.K., which opened in 1988 in *Chemistry International*. According to Allison, the museum offers over 100 interactive exhibits, computers, and puzzles, focusing on chemistry and the chemical industry and the vital role they play in visitors' everyday lives. It touts over 40,000 visitors a years, with 18,000 being school children on field trips.

While some examination of chemistry exhibits has occurred within science museums, none have focused on visitor learning from these exhibits. Instead, study of learning in these environments has focused on exhibits pertaining to biology and physics, due in-part to the large number of available exhibits and the popularity these exhibits have with the visitors to science museums. To this extent, much of the discussion on learning in the following sections will focus on learning at science museums in general and biology and physics exhibits in particular.

Learning in Informal Settings

Learning occurs in a variety of settings. It can be a result of watching someone demonstrate or perform a task, reading a book, or listening to a lecture. Learning in informal settings, such as science museums, science centers, zoos, arboreta, and aquaria, typically occurs as a result of unplanned interactions on the part of the visitor with content knowledge provided by the institution. Within the context of a science center, many of these interactions can be perceived as entertaining and fun, which leaves many parents asking, "did they learn from these experiences?" The learning environment in science museums is vastly different from the environment found in school, with more colors, noises, unstructured interactions, and little formal guidance through the material. Wellington (1990) summarized some of the differences between formal and informal learning environments, as shown in Table 2.2. Interactions in informal settings are voluntary, haphazard, open-ended, unplanned, and with many unintended outcomes. In contrast, interactions in formal settings are compulsory, structured, more close-ended, planned, and with fewer unintended outcomes. Many of these differences add to the complexity involved in studying environments of this nature. Voluntary and unstructured interactions result in many variables being identified to describe visitor interactions within the exhibit. This compounds when researchers attempt to track a number of individuals within a visiting group. As alluded to by Falk and Dierking (1995), no two visitors come away with the same outcomes, even when they visit the museum together.

Table 2.2: Comparison of Informal and Formal Learning in Science

Informal Learning	Formal Learning
Voluntary	Compulsory
Outside of formal settings	Classroom and institution based
Haphazard, unstructured, non-sequenced	Structured and sequenced
Non-assessed, no degree granted	Assessed, degree granted
Open-ended	More closed-ended
Learner-led, learner-centered	Teacher-led, teacher-centered
Unplanned	Planned
Many unintended outcomes (outcomes more difficult to measure)	Fewer unintended outcomes
Social aspect central, e.g. social interactions between visitors	Social aspect less central
Low 'currency'	High 'currency'
Undirected, no legislated for	Legislated and directed (controlled)

Adapted from: Wellington, J. (1990). Formal and informal learning in science: the role of the interactive science centres. *Physics Education, 25*, 247-252.

What people learn from science museum and science center experiences has been studied from many angles: (1) entertainment (Allen, 2004), (2) behavior (Boisvert & Slez, 1994; Boisvert & Slez, 1995), (3) visitor characteristics such as prior knowledge (Falk & Adelman, 2003), agenda (Falk, Moussouri, & Coulson, 1998), memories (P. McManus, 1993; Medved & Oatley, 2000), and meaning making (Rahm, 2004), (4) exhibit characteristics (Boisvert & Slez, 1995; Falk, 1993, 1997), (5) use of interactives (Falk, Scott, Dierking, Rennie, & Jones, 2004), (6) visitor perceptions, and (7) use of time (Falk, 1982b, 1983b). The type of institution visitors frequent can also be an indication of the material they are learning. In Britain, it is estimated that 74 million people visited museums in 1990, including the British Museum, National Gallery, Natural History Museum, and Science Museum (Hooper-

Greenhill, 1994, p. 60). In America, estimates from the National Research Center for the Arts indicate that 56% of the public visit a history museum once a year, with fewer people visiting art and science museums (Hooper-Greenhill, 1994, p. 61).

Gains in specific content knowledge are one of the harder aspects of visitor learning to obtain. Attention to content varies with interest (Csikszentmihalyi & Hermanson, 1995; Falk, 1983b), agenda (Falk et al., 1998; K. B. Lucas, 2000), and time in the exhibit (Dierking & Falk, 1994; Falk, 1983b). How individuals are able to deal with novelty has also been shown to effect visitor learning (Kubota & Olstad, 1991; Sandifer, 2003). Individuals who were oriented to the setting prior to their visit had higher content knowledge gains than those who had not been oriented (D. Anderson & Lucas, 1997).

Socio-Cultural Constructivist Theory

The constructivist theory of learning views knowledge as being constructed in the mind of the learner (Bodner, Klobuchar, & Geelan, 2001). Knowledge is viewed as not being imparted from the teacher to the learner as an intact whole. Instead, bits and pieces of knowledge are built up through connections made to prior knowledge held by the learner and through interactions with others. As such, constructivist theory views knowledge as being built up in the mind of the learner. This knowledge is most useful within the context in which the knowledge was built and where it functions successfully. From the standpoint of a learner, chemistry only resides in chemistry class, math only in math class, physics in physics, without seeing the greater picture of how these disciplines overlap. To provide the larger knowledge context, teaching must establish that mathematical knowledge is applicable to chemistry and physics and the everyday world.

Socio-cultural constructivism places more emphasis on group interactions for building knowledge, rather than on interactions of new knowledge with the learner's prior knowledge. Knowledge, in this case, is solidified through talking about problems with both novice-level peers and experts. A give-and-take conversation is used to hone in on the understanding held by the expert and by the learner while at the same time allowing the learner to receive feedback from the expert and/or other peers. The interactions between members of social groups have stronger influences on the development of knowledge, as they are more frequent and last longer than interactions between novices and experts.

Culture also plays a role in how individuals understand new knowledge. Using an empiricist view, science is seen as having a definable culture separate from the culture of the learner and, as such, science education should reflect science as much as possible (Cobern, 1998). So, while science has connections with the natural world, it lies outside of the student's social world. The gap between what students are familiar with and the nature of science, has led students to feeling that science, as it is being taught in school, has nothing to offer them within the cultural and social environments to which they are accustomed. This leads to the idea that physics and chemistry only occur within the context of the classroom. In contrast, the social constructivist view of science moves the connection between science and the natural world farther apart, such that science lies outside of cultural differences and works to connect knowledge from across different ethnic cultures. In essence, this view provides a context for science that links science in the classroom with the students' world. The goal of science education is then to bridge the gap between the students' culture and knowledge created using scientific methods. In this view, topics, such as improvements in agriculture, development and the underlying technology of electronics, and current events can be used to teach scientific theory and applications to students through the development of student interest.

Contextual Model of Learning

The Contextual Model of Learning describes the complexity of informal learning environments by viewing learning as inherently personal. The personal nature is a result of interactions between the individuals' personal, social, and cultural (socio-cultural) contexts, as well as the physical environment, as the individual's interpretation of these contexts change over time (Figure 2.3). Learning is therefore "the process / product of the interactions between these three contexts" (Falk & Dierking, 2000, p. 10). Within the three contexts are underlying factors that work to explain how the contexts interact (Table 2.3). Each context will be discussed individually and in terms of the appropriate key factors.

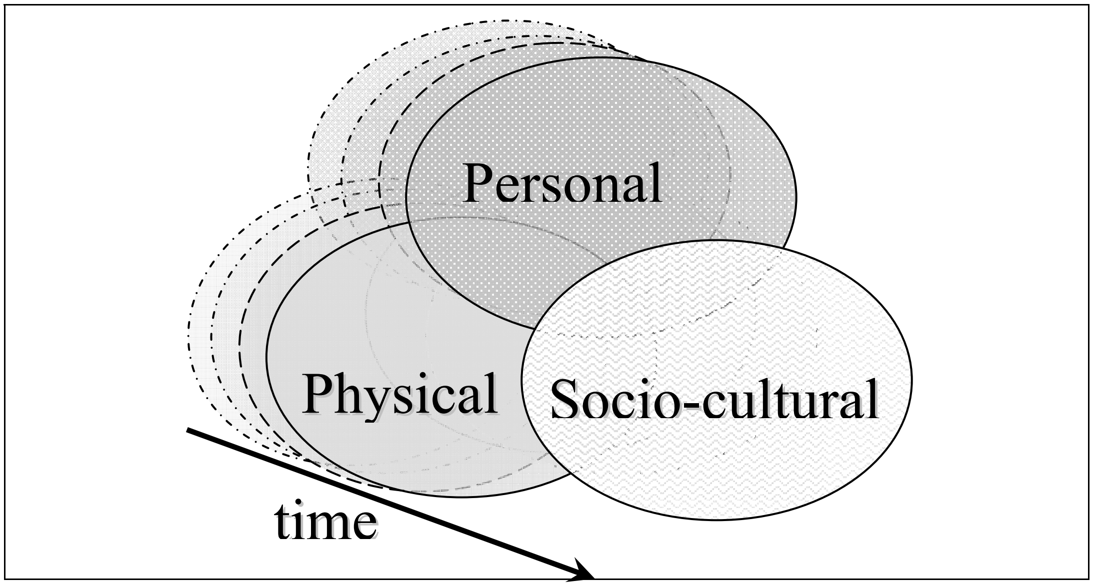


Figure 2.3: Contextual Model of Learning.

Knowledge is shaped by the overlap of the three contexts: personal, physical, and socio-cultural over time. Adapted from Falk, J. H., & Dierking, L. D. (2000). *Learning from Museums: Visitor Experiences and the Making of Meaning*. Walnut Creek, CA: AltaMira Press. (p. 12)

Table 2.3: Key Factors Within the Personal, Socio-cultural and Physical Contexts

- Personal Context
  - Motivation and expectations
  - Prior knowledge, interests, and beliefs
  - Choice and control
- Socio-cultural Context
  - Within-in group socio-cultural mediation
  - Facilitated mediation by others
- Physical Context
  - Advance organizers and orientation
  - Design
  - Reinforcing events and experiences outside the museum

Adapted from: Falk, J. H., & Dierking, L. D. (2000). *Learning from Museums: Visitor Experiences and the Making of Meaning*. Walnut Creek, CA: AltaMira Press. (p. 137)

Personal

Learning is personal. It is stimulated by appropriate motivational and emotional cues, facilitated by personal experience and knowledge, constructed from prior knowledge, and expressed within appropriate contexts, such that "most human learning is self-motivated, emotionally satisfying, and very personally rewarding" (Falk & Dierking, 2000, p. 16). The driving force of the personal context, motivation, is influenced by interest in the subject matter (Schiefele, 1991). Interest involves both feeling- and value-related characteristics, that is, an individual's emotional attachment to the content (as enjoyment or involvement for example), and the significance of the experience within his or her life (Paris, 1998). Work by Falk and Adelman (2000; 2003) has shown that visitors to science centers with the least knowledge and most prior knowledge, and those with moderate to extensive interest in the content presented showed significant knowledge gains after their visit. Many researchers have also looked at the value of immersion environments on student interest when visiting science museums and found positive relationships between knowledge gains and interest in the content (Hickey, Petrosino, & Pellegrino, 1994; Jarvis & Pell, 2005).

Visitor research has identified some of the motivations visitors have to visit science museums. Hood (1983) found that museum-goers usually have high intrinsic motivations due to the value they place on learning. Many seek the challenge of exploring and discovering new things and place a high value on doing something worthwhile. Falk (1998) found a strong correlation between visitors' value of learning and their level of education. In general, people who think that learning and education are important continue on with higher education and seek out other vehicles through which they may learn. Some of these individuals may have been taken to a museum as a child by their parents, having the value of these experiences instilled from childhood. This component has implications on the demographics of museum-goers, as many minorities, recent immigrants, and the economic under-class had fewer of these opportunities as children (Falk, 1998, p. 41).

Motivation to find informal learning experiences can be extrinsically or intrinsically caused. Intrinsically motivated individuals typically receive no reward for their participation other than the joy of the experience. One such experience, *flow,* has been studied extensively by psychologist Mihály Csíkszentmihályi. In his text, *Flow: The Psychology of Optimal Experience*, Csíkszentmihályi defines flow as an experience that uses all of the individual's consciousness and focuses it on a task, in a sense of altered consciousness, leaving the person feeling intrinsically rewarded (1990). To reach and maintain this state then motivates individuals toward the intrinsic reward. These experiences can be found in science centers, as the flow of mind, consciousness, and focus described by Csíkszentmihályi (1988, p. 30) thrives on challenges that are slightly above the ability of an individual. As such, exhibits that harness this motivation at an appropriate level for the average visitor will result in optimal attention and should result in increased amounts of learning.

Curiosity is a specific intrinsic motivation that museum settings rely on in children and adults for learning to occur; conversely curiosity and intrinsic motivations are down-played in our formal education system (Semper, 1990). It is the natural curiosity that drives the haphazard interactions with exhibits, social interactions with peers, and many unplanned and unintended outcomes of a science museum visit. As a researchable phenomenon, "curiosity refers to individual differences in the likelihood of investing psychic energy in novel stimuli" (Csikszentmihalyi & Hermanson, 1995). Interest, on the other hand, refers to the likelihood of investing this energy in one set of stimuli over another.

Socio-Cultural

Part of the science museum environment is the noise from visitors interacting with each other as they explore exhibits. Adults read signs to children and talk about how the content relates to other aspects of their lives. Exhibit designers communicate to visitors' through the visitors' content knowledge using signage and displays within the exhibit. The ability to interact using a common knowledge base is learned through these types of interactions with others in the society. Humans are social beings such that much of what we learn is a product of conversation, gestures, emotions, observations, and the use of culturally and historically constructed tools, signs, and symbol systems (Falk & Dierking, 2000). Interactions between members of a society establish and solidify cultural norms and values that are then taught to newer members (White, 2002).

The social or cultural transmission of knowledge allows access to knowledge gains by previous generations through books and oral histories. This ability for shared experiences, beliefs, customs, and values make up what is called culture (Falk &

Dierking, 2000). Culture is viewed as an adaptation enabling individuals to survive as part of a group. Society then influences what content is learned and to some extent how it is learned in order for adults to meet cultural imperatives. Ogbu ascribes five components to the cultural world: 1) customary ways of behaving, 2) codes or assumptions, expectations, and emotions underlying the customary behaviors, 3) cultural artifacts, 4) institutions, and 5) patterns of social relations (1995). Science museums need to address the customary behaviors of different cultures whose members visit science centers, whether its in the spatial design of exhibits or choice of language in signage (White, 2002).

Physical

In addition to addressing visitors' customary behaviors, many science museums have their own customary behaviors. Unlike art museums, which are typically quiet and sparse, science museums are loud, colorful, and full of things to do. Barker and Wright (1955) describe "behavior settings" such as required in these situations as a standing behavior pattern for a particular context and the physical environment in which it occurs. First time visitors have many environmental cues to absorb, such as the appropriate level at which to converse, appropriate attire to wear, location of restrooms and concessions, what exhibits are available, what there is to do within the exhibits, and what can and cannot be touched. Such behaviors are learned through visiting the museum environment or from others who have already visited. Frequent visitors already know their role within the science center. They are aware of where things are located and what is available to do and see. For later visits, they arrive oriented and so are able to look at details they previously missed and learn from the content presented. As learning is bound to context and therefore the behavior setting, the frequency of visitation to science museums becomes important (Falk & Dierking, 1992, p. 26). Time is needed for visitors to orient themselves to the new "behavior setting" that is defined as the science center (D. Anderson & Lucas, 1997; Falk & Balling, 1982; Falk, Martin, & Balling, 1978; Gennaro, 1981; Kubota & Olstad, 1991). Without this adjustment period, learning becomes secondary in nature to reducing the novelty related to the new environment (Falk, 1983a).

To address the adjustment period and aid in learning, researchers have studied the use of advance organizers for students attending as part of a field trip. Advance organizers act to organize information contained within new behavior settings by giving an overview of the content of the field trip in an abstract manner (Abad, 2003). These include pre-trip visits by museum staff to the classroom (D. Anderson & Lucas, 1997) and overviews of the field trip conducted by teachers (Gennaro, 1981; Kubota & Olstad, 1991). Use of advance organizers has been shown to increase students' learning during field trips. Few studies have focused on the effect of advance organizers on the general visiting population to science museums.

Summary

Descriptions of interactive chemistry exhibits in the science education literature are sparse. Most articles focus on historically themed displays lacking in hands-on approaches to learning. While some science museums, like the Exploratorium and the Museum of Science and Industry offer displays on current chemistry research, most do not offer visitors the ability to participate in interactive activities. Theories describing the nature of learning in informal settings focus on the need for interactive environments to promote learning. Two in particular, the socio-cultural constructivist theory and the Contextual Model of Learning, emphasize the importance of interactions between visitors, their prior experiences, and the important role of passing time during knowledge construction. In the next chapter, the methodology of the study will be discussed.

Chapter 3

Methods for Measuring Informal Learning at Science City

Measuring Informal Learning

Measuring outcomes of informal learning focuses largely on two groups: school groups on field trips and family groups. As school groups are easier to study using an experimental design, the bulk of the available research focuses on this area. Field trips offer researchers pre-defined groups of students from diverse backgrounds, usually randomly placed in classes. Reasons for field trips are also widely varied: to expand students' horizons, to promote socialization skills, and/or to reinforce classroom lessons and expand cognitive abilities (Falk et al., 1978). Studies in this area look at the effect of and ways to reduce novelty related to learning (D. Anderson & Lucas, 1997; Falk, 1983a; Falk et al., 1978; Gennaro, 1981; Kubota & Olstad, 1991; Martin, Falk, & Balling, 1981) and how the environment affects learning (Falk, 1983b; Gennaro, 1981; Morrell, 2003; Orion & Hofstein, 1991a) using pre/post test methods (D. Anderson, Lucas, Ginns, & Dierking, 2000).

Family groups and general visitors to science centers are more difficult to study. Variables such as behavior, group interactions, agenda, time allocations, and attention cannot be controlled as desired in typical experimental designs (Dierking & Falk, 1994). Studies of family groups have focused on how they interact with the exhibits (Diamond, 1986; Falk & Dierking, 2000) and what learning visitors take away in the short-term (D. Anderson et al., 2000; Borun, Chambers, & Cleghorn, 1996; Falk, Koran, & Dierking, 1986). Typical tools have included concept maps (Diamond, 1986), observations (Diamond, 1986, 1999; Falk, 1983b), tracking (Sandifer, 1997), video-tape surveillance (Borun et al., 1996), surveys (Falk &

Adelman, 2003), interviews (Boisvert & Slez, 1995), and focus groups (Dierking & Pollock, 1998).

Development of the tools used in this study was based in part by work done by Borun, Chambers, and Cleghorn (1996) on family learning in science museums, Hickey, Petrosino, and Pellegrino (1994) on emersion experiences at the Challenger Learning Center's M.A.R.S. exhibit, and Pell and Jarvis (2001) on effect of the Challenger Learning Center on student attitudes toward science and space. Borun, Chambers, and Cleghorn studied family groups at four museums in the Philadelphia area: the Franklin Institute Science Museums, the New Jersey State Aquarium at Carnden, the Academy of Natural Sciences, and the Philadelphia Zoological Garden. The researchers used interview questions to collect data from the family unit and applied a behavior coding sheet to record the interactions between the family and the exhibit. They found a relationship between learning levels and observable behaviors in individuals, as well as a group effect thought to be due to the shared cultural knowledge and experiences that can be used to relate material amongst members of the group. In a related study, Borun, Chambers, Dritsas, and Johnson (1997) also found that exhibits which allow for more family interactions can increase the amount of learning behaviors seen.

Work by Hickey, Petrosino, and Pellegrino (1994) focused on the Challenger Learning Center's M.A.R.S. (Mission Assignment: Relief and Supply), an emersion experience where students simulate a mission to Mars, shows that giving science a context results in a positive impact on students' interests, attitudes, knowledge, and activities relative to both science and space science. The M.A.R.S. learning activity focuses on developing (1) interest in science, mathematics, and technology, (2) communication, cooperation, critical thinking skills, and problem solving skills, and (3) student autonomy and responsibility for learning (Jarvis & Pell, 2002). Hickey et al. surveyed school groups before and after their visit to Challenger and found that groups which had participated in the program the previous year had higher interest in and value of learning about space travel and science and higher interest in science topics and that the social aspects of assigned tasks within the program influenced students' interest in the task. The focus on the emersion process as it influences attitudes towards science and space, as well as work done by Pell and Jarvis (2001), was used to guide the development of the attitude questions in this study. This work is described in more detail later in this chapter.

Research Design

This study uses a repeated measures design to look at the change in visitors' perceptions of learning at the *Astronaut Training Center* (ATC) in Science City. Visitors were initially surveyed when they completed viewing the exhibit using a combination of 5-point Likert scale and open-response questions. Visitors were also asked to complete a follow-up survey sent to them some months after their visit to determine the change in their initial perceptions. A rubric was also created to track which exhibits visitors interacted with during their visit and if visitors interacted with one another during their visit in order to provide additional validity to the visitor survey. The educational staff was also surveyed to obtain an additional perspective on visitors' experiences, outside of the researcher's observations. The behavior analysis was conducted on days the survey was not given; the educational staff survey was not given until after the completion of the initial visitor survey.

Setting and Context

Science City is located in Union Station in downtown Kansas City, Missouri. As an interactive science center, Science City is designed to place science within the context of a city and not isolate scientific phenomena. Typical exhibits include the *Storm Center, Body Tours, Astronaut Training Center, and Crime Lab* (Figures 3.1 and 3.2, see Appendix I for a map of Science City). The *Storm Cente*r (Figure 3.1) simulates a television weather station as meteorologists track a storm front moving through the Kansas City area. Visitors can view the humidity, air pressure, and wind speed while interacting with the simulation. Visitors also have the opportunity to see a tornado form and to create sand dunes using a rotatable fan. The *Body Tours* (Figure 3.2) is a facilitator-led exhibit that takes visitors through a patient's open heart surgery, traveling through a major artery, seeing clogged arteries, and feeling the stress put on the heart up until the patient has a heart-attack and is rushed to the hospital for surgery. This exhibit ends with emergency surgery on the patient, where visitors can see a video of an actual surgery being conducted, with image projected through a screen placed within a manikin's chest. The *Astronaut Training Center* and *Crime Lab* will be described later in this chapter.

Chemistry within Science City

The summer prior to beginning the study, observations of Science City were made to determine the best exhibits to study. Focus was initially put on finding an exhibit with chemistry content and comparing it to ones without. After examination of the exhibit content, the *Crime Lab* was selected for examination due to its emphasis on forensics. Visitors were provided a detective's Case Files describing a crime that had occurred and were asked to solve the crime using the tools available in the exhibit. Visitors can examine finger prints, interact with a sketch artist, and examine hair samples. While chemistry was not directly presented, this exhibit had the strongest underlying chemistry theme of the interactive exhibits due to its focus on forensics.

While the *Crime Lab* exhibit had the most chemistry-related content, examination of this exhibit would have been difficult. The *Crime Lab* did not have as many visitors interacting with the stations as seen in many other exhibits at Science City. Education facilitators at Science City believe that the way the exhibit is set up had a negative effect on the way visitors interacted with it. Visitors were unsure how or if to use the "Case Files" provided to go through the exhibit stations. Many visitors only walked through the exhibit looking at the stations, or interacting with the stations by viewing what was available. Based on observations by the researcher and on conversations with the facilitators, no visitors actually picked up the file folders and worked through a complete case as the exhibit designers had intended.

Figure 3.1: *Storm Center* (left) and *Crime Lab* (right) on Upper Level at Science City

Figure 3.2: Lower Level *Tot Park* (center), Periodic Table Café (upper left) and *Body Tours* (upper right) at Science City

The Periodic Table Café had the largest, most obvious chemistry theme of any of the areas in Science City. The working café is decorated with laboratory glassware, strongly reflective of the stereotypical chemistry lab. Books were also on display, showing chemistry as it was pursued through history. All chemistry content in this area was behind glass and did not promote hands-on interaction. None of the displays were designed to be handled. Even the large-scale Periodic Table hanging behind the café was a basic table, with atomic numbers, symbols, and names, lacking any sense of personal connection for visitors. Research indicates that this type of personal interaction is needed to engage novices in modern chemistry content.

Astronaut Training Center Exhibit

The *Astronaut Training Center* (ATC) was selected for study based on its popularity among visitors and on recommendations by Science City staff for its high quality presentation. Prior to formal selection, all available exhibits were scouted for content and popularity to ease analysis. Neither of the two previously described chemistry exhibits (the *Crime Lab* and Periodic Table Café) had both the appropriate content and visitor traffic flow needed to produce the desired effect size.

The *Astronaut Training Center* consists of four rooms: an initial entry, the Space Station Mars, Habitat Module, and the Training Module (Figure 3.3). When first approaching the *Astronaut Training Center*, visitors are greeted by an astronaut's space suit (Figure 3.4). In the initial entry, visitors can view a display case containing spacesuits, dehydrated food, toiletries, and even a tire from the space shuttle (Figure 3.5). Visitors can also interact with the Shuttle Flight Simulator, a video-game like

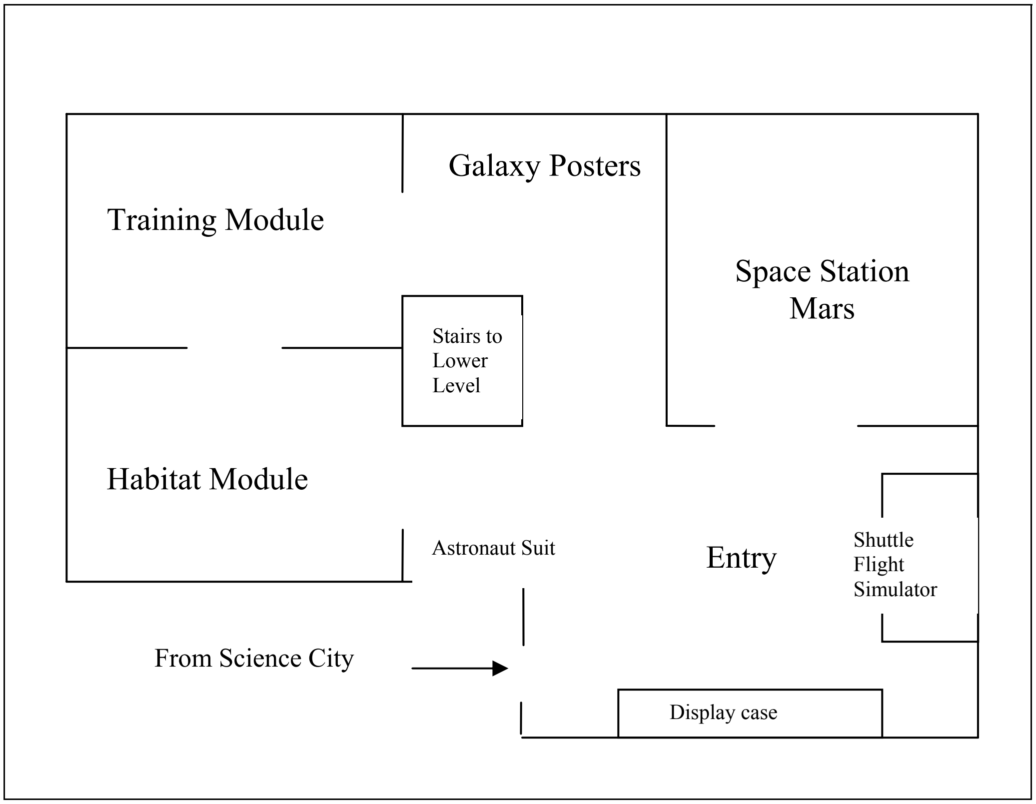


Figure 3.3: Diagram of the *Astronaut Training Center* – not drawn to scale

simulator which allows visitors to sit in the cock-pit and land the shuttle at various sites and under various landing conditions. Off of the entry, visitors encounter the Space Station Mars, which simulates a control room in a fictional space station. Visitors can drive a rover remotely via a television feed to explore the Mars surface or control a rover from a viewing station. Visitors can also test Mars soil samples to determine the radioactivity, water content, and magnetism of a sample (Figure 3.6). The station is decorated with posters showing Mars and statistics comparing Mars with Earth.

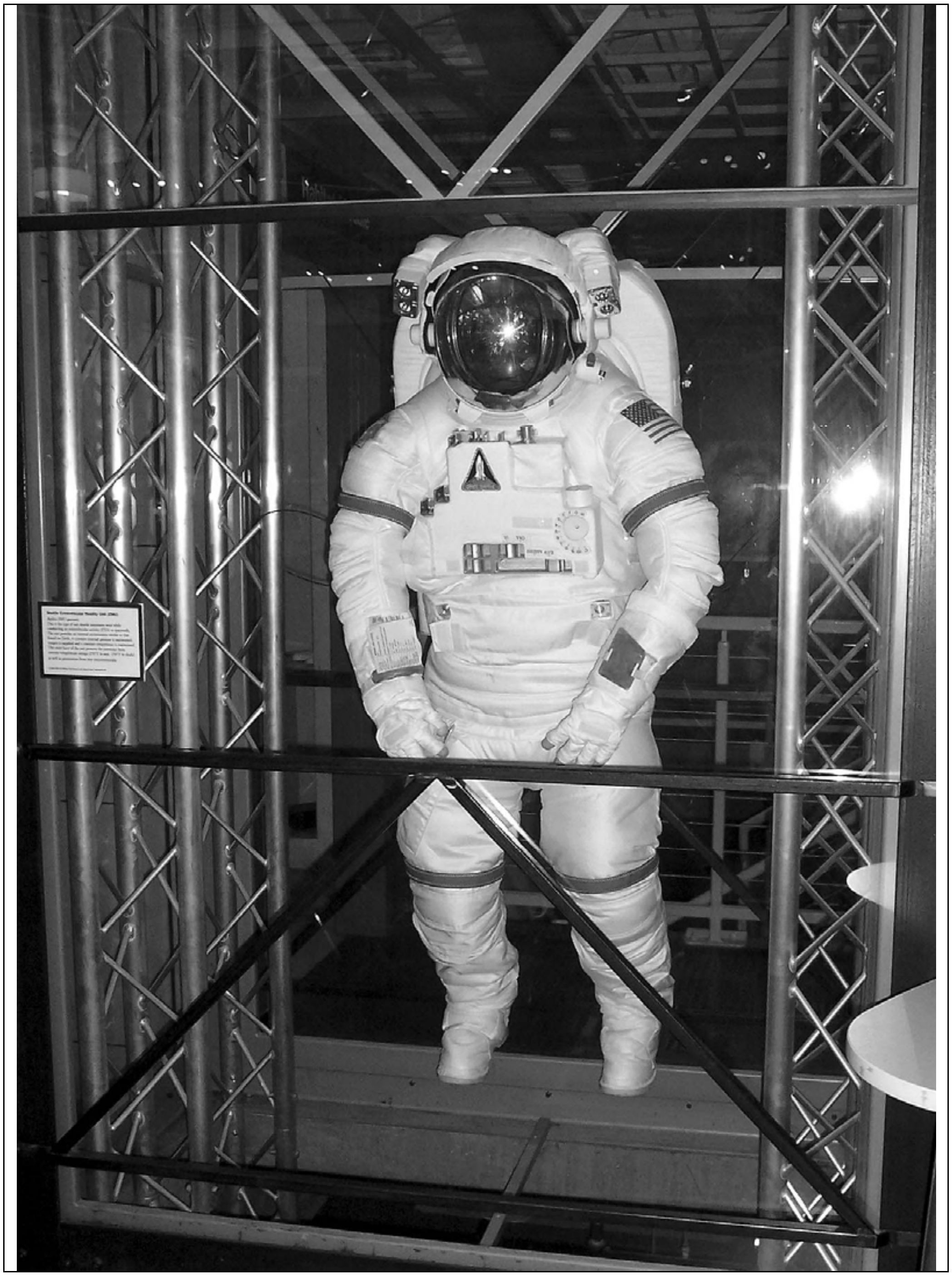


Figure 3.4: Astronaut Suit on Display in the *Astronaut Training Center*

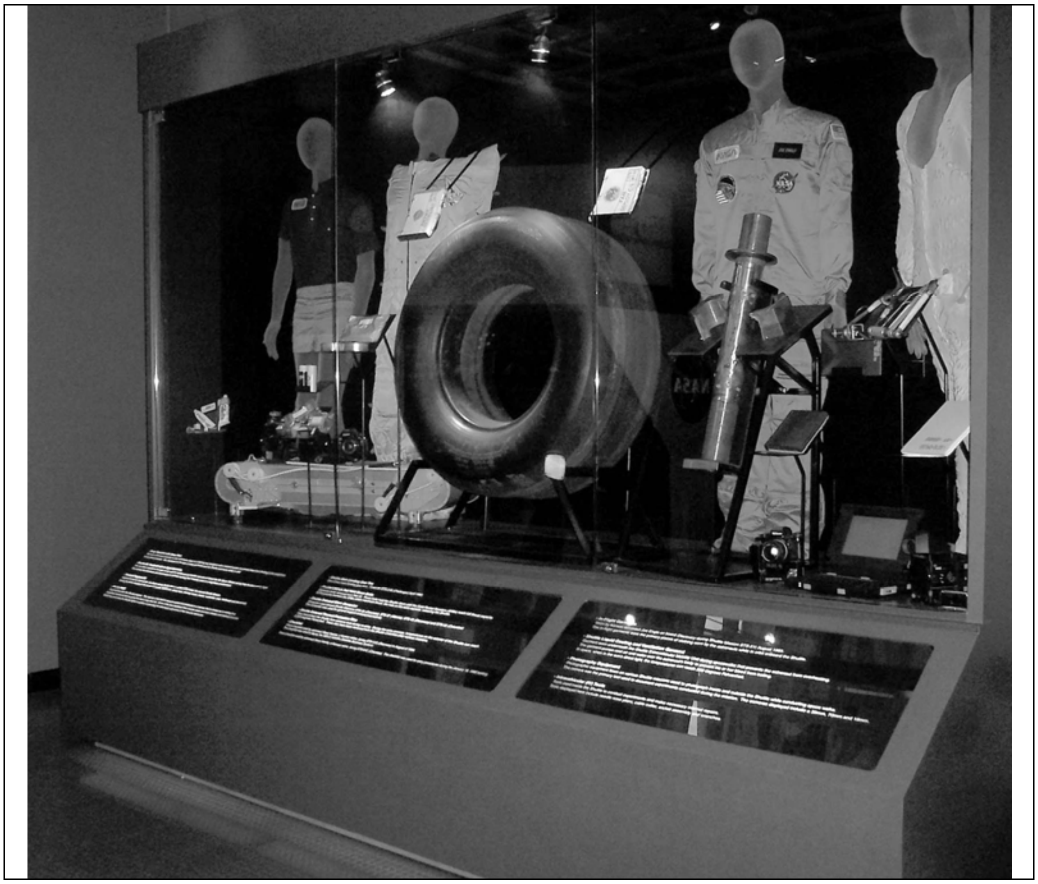


Figure 3.5: Display Case in Entry Room to *Astronaut Training Center*

The Habitat Module and Training Module are connected rooms that link back to the entry. A catwalk between the entry and the Training Module is decorated with posters of galaxies taken by the Hubble Space Telescope. Each poster has an audio commentary that gives visitors information about the galaxy, which is activated by simply touching the poster. In the Training Module, visitors have many interactive stations to explore. Upon entering the Module, visitors can try the Dizziness Challenge to see if the rotation of the space station has an effect on their balance and depth perception. Once visitors have regained their balance, they can move on to the

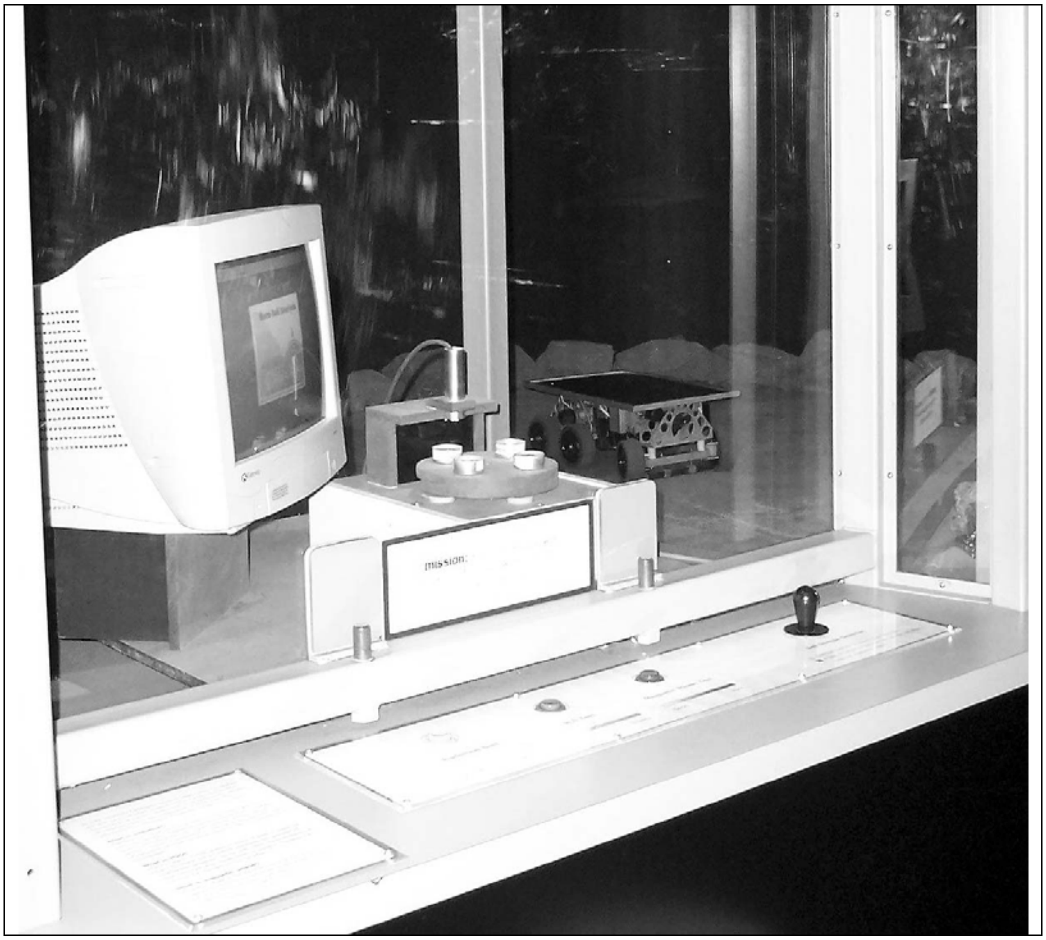


Figure 3.6: Mars Soil Test

Satellite Orbiter which allows visitors to control the booster rockets on a simulated craft orbiting the Earth. A Moon Atlas is also available for visitors to learn more about the lunar conditions through interactions with a video display. From there, visitors can monitor their heart rate as they peddle a bicycle that simulates for them training in space at the Fitness Test station. Then visitors can use a Robotic Arm to place a ping-pong ball through a hoop to practice eye-hand coordination and fine-tune skills using remotely operated machinery. Next is the Earth Monitor, where visitors use a simulation to model the identification of unknown objects entering Earth's atmosphere. Finally, prior to entering the Habitat Module, visitors participate in the Emergency Repairs station, flipping knobs to restore power and repairing a satellite from the space station.

In the Habitat Module, visitors can experience living and working conditions within a simulated space station. The walls within this room display the sleeping areas used by astronauts, first-aid kits, storage, hydroponics chambers used in experiments on board the space shuttle, and even a space toilet. With the exception of the space toilet, these displays are meant to be looked at rather than used. The Compatibility Test is the only fully interactive station in this module. In it, visitors can work together to center the Earth on a video display in order to prepare the shuttle to land.

Sample

Between January and December 2004, 100 adults and children visiting Science City alone or part of a family group participated in the study. Information regarding the individuals' demographics, such as gender, age, level of education, reason for visit, and race/ethnicity was collected for comparison with previous work and the visiting population seen at Union Station (Table 3.1). Comparison of the sample data with data collected by Union Station using a Chi-squared analysis showed no statistically significant differences between the two groups.

Table 3.1: Percentage Comparison of Science City Visitor Population and Study Sample.

	Union Station[a]	This Study (n = 100)
Sex[b]		
Female	60	54
Male	40	38
No response given		8
Race/ethnicity[c]		
Caucasian	86	84
African American	9	2
Asian	2	2
Hispanic	2	1
Other		4
No response given		7

[a] From *Union Station Kansas City Demographics*, by Blue Water Consulting, Inc., 2002. Kansas City, MO.
[b] Chi-squared = 0.001; $p = 0.971$
[c] Chi-squared = 8.632; $p = 0.071$

A follow-up survey was sent to volunteers for completion approximately three months from the end of data collection. Demographic information was not collected again at this time as it was previously collected on the initial survey. The volunteers were asked to indicate the last four digits of their phone number in order to match the initial and final survey. Many respondents did not comply with this request so many responses could not be matched to the appropriate initial visitor surveys.

Following the completion of the initial visitor survey, the educational staff of Science City was asked to complete a similar survey. The educational staff surveyed consisted of the five facilitators assigned to Science City on the day the survey was given, and their three supervisors. Demographic data was not collected from the staff;

though based on general observations, the staff ranged in age from 18 to mid 60's and were generally all Caucasian.

Development of Tools – Multi-Method Design

As many of the tools available to study learning in science centers are highly context specific, new materials had to be developed to address the specific design of the *Astronaut Training Center* exhibit. A review of the literature revealed some previous research material adaptable to the environment at Science City. A multi-method design was used to provide multiple perspectives on visitors' interactions within the exhibit. Two visitor surveys collected information regarding visitors' perceptions of their learning during their visit and determined with what exhibit stations visitors interacted. A rubric was used to collect observational information regarding visitor behavior as well as to provide some check of the reliability of visitors' self-reported interactions. The final approach was to survey the educational staff at Science City to determine how they feel visitors' interacted with the exhibit. Information regarding the staff's attitudes toward and perceptions of the nature of science were also collected.

The initial and follow-up surveys were developed using a combination of two approaches: a socio-constructivist model of learning and Falk and Dierking's Contextual Model of Learning (2000). Both models focus on the individual constructing knowledge based on his or her experiences with the environment and individuals within it. Falk and Dierking's model in particular emphasizes the importance of context and socio-cultural experiences on how visitors to science museums construct knowledge based on their experiences. This model is standardly used in studies of this nature.

Four dependent measures were identified for investigation. The first, visitor perception of learning, was identified to probe visitors' learning though interacting with the exhibit space. The perception recognizes the difference between conscious learning as seen in direct formal education and the unconscious, non-formal and informal learning occurring in these facilities. As many learning outcomes are possible in informal learning environments (Falk, 1998, 1999; Falk & Adelman, 2003; Falk et al., 1986; Falk et al., 1978; Falk et al., 1998), we will only focus on the learning related to this exhibit. This study is limited then by the amount of attention visitors are willing to give to the exhibit and the survey process during their visit. A repeated measures design was used to assess visitor learning. The nearly identical initial visitor survey and follow-up visitor survey are described in detail later in this chapter. The initial survey was given to visitors on-site immediately following their visit to the *Astronaut Training Center*. This paper and pencil questionnaire consisted of both Likert scale items and open-ended questions. The follow-up survey was administered as either an online questionnaire or as a mailed questionnaire, depending on the type of information left by visitors choosing to participate in the follow-up. To validate visitors' experiences, a behavioral rubric was developed to track visitor interactions throughout the exhibit. A survey of educational staff was also conducted on-site, after the completion of data collection for the initial visitor survey.

Visitor attitudes towards space, science and the exhibit were identified as the remaining three dependent variables. Many have previously identified the importance that science centers can have on students' views of science (Brody, Tomkiewicz, & Graves, 2002; Jarvis & Pell, 2005; Orion & Hofstein, 1991b; Russell, 1990; Schibeci, 1990). Items in this study were based on the attitude survey developed by Pell and Jarvis, which probes high school students' attitudes toward science (Pell & Jarvis, 2001). Questions constructed by Pell and Jarvis focused on science enthusiasm, social context, science interest, liking school, science being difficult, and being an independent investigator. The initial survey focused on questions from the first three categories: science enthusiasm, social context, and science interest. These items had to be revised to fit the context of the *Astronaut Training Center*. New items were aimed at personal enjoyment, social context, and science interest.

The behavior rubric was adapted from the rubric designed by Borun, Chambers, and Cleghorn (1996) to evaluate visitor interactions at exhibits in the Franklin Institute of Science Museum, the New Jersey State Aquarium at Camden, the Academy of Natural Science, and the Philadelphia Zoological Garden. This rubric consisted of thirteen behavioral categories for observation, divided into seven groups (Table 3.2). These behaviors were also observed in visitors to the *Astronaut Training Center*, so a rubric appropriate for the *Astronaut Training Center* was developed (see Appendix VI). Unlike the previous rubric by Borun et. al., this rubric collected information regarding the association of behaviors with specific elements of the exhibits and whether it was an adult or child interacting with the exhibit.

Table 3.2: Common Behaviors Performed by Family Groups in Science Centers*

Interactions between actor and receiver	
Logistical	
	call someone over
	point at exhibit
	approach
	withdraw
	climb on/through
Conversation	
	verbal observation/explain
	ask question
	answer question
	express like
	express dislike
Use graphics	
	Read label/picture silently (2 sec)
	Read label aloud
Continuous behavior	
	Hands-on
	Sequence number
	Time
Observe Only	
Non-exhibit behavior only	

* *Note*: Table adapted from Borun, M., Chambers, M., & Cleghorn, A. (1996). Families Are Learning in Science Museums. *Curator, 39*(2), 123-138.

<u>Initial and Follow-Up Visitor Survey</u>

The initial visitor survey consisted of three parts: interactions with the exhibit (30 items), visitor attitude toward the exhibit and science in general (30 items), and visitor demographics (15 items) (see Appendix II). The first section, Interaction, focuses on what stations visitors manipulated during their visit (7 items): Shuttle Approach Simulator, Mars Rover, Mars Soil Test, "Compatibility Test," Robotic Arm, Astronaut Fitness Test, and "Emergency Repairs" Knobs. This section also asked visitors to rate how much they used these stations (11 items), and read the signage (7 items). Visitors were also asked to rate how much they socialized with members of their group, other visitors in the exhibit, and Science City facilitators about the exhibit content (4 items). Questions were rated on a 5-point Likert scale describing the amount that visitors manipulated the station with 1 indicating "not at all," 3 "some," and 5 "a lot." This section also included questions regarding how much visitors guided others through the exhibit, and read the signage. Questions about the exhibit signage were in the form of yes/no statements and focused on whether or not visitors read the signage, whether they did what the signage said, and if the signs addressed the questions visitors may have had. Visitors were also asked if they would like more information regarding the stations.

The second section focused on visitor attitudes toward space and science. Questions for this section were also in a 5-point Likert scale format. Ten items focused on the visitor's attitude toward the *Astronaut Training Center*. These questions focused on visitor experiences in the exhibit to examine if their attitudes changed between the initial and follow-up survey. Fourteen statements focused on general attitudes toward science and learning. These statements focused on how respondents' knowledge of the nature of science, tendency to seek out other science education resources, and feelings about whether others in their group enjoyed the visit.

This section also contained three open-ended questions, focusing on (1) what visitors felt they learned from the exhibit, (2) what they felt the exhibit was trying to show and (3) what came to mind when they thought about the exhibit. A rubric was developed in order to score the open-ended questions following the learning behaviors developed by Borun, Chambers, Dritsas, and Johnson (1997) (see Appendix V for rubric). Each response was read and assigned a value based on the level of explanation given: identifying, describing, and interpreting and applying (Table 3.3).

Table 3.3: Learning Levels Used To Score Open-Ended Questions

Level	Description	Example
One - *Identifying*	• One word responses • Few associations with exhibit content • Connection to content miss the point • Contains many misconceptions	Space. "Mars info." Astronauts. "NASA."
Two - *Describing*	• Correct connections with visible exhibit characteristics • Connections with personal experience • No extensive misconceptions	Describes manipulating the Robotic Arm. Describes the environment of the exhibit. "landing the shuttle & how hard everything was"
Three - *Interpreting and Applying*	• Correct statements of concepts behind the exhibits • Connection of exhibit concepts to life experiences • Little to no misconceptions	Interprets and relates content to personal experiences and why things are done in certain manners. "Realized the difficulties of exploring other planets."

Adapted from: Borun, M., Chambers, M., & Cleghorn, A. (1996). Families Are Learning in Science Museums. *Curator, 39*(2), 123-138.

Demographic information regarding the visitor's level of education, college major (if applicable), annual household income, and ethnicity was collected for comparison with other studies on the visiting population of science museums. Information about visitors' reasons for their visit, if they had visited before, and the size of the social group they came with was also collected to gain insight to visitor agenda. All participants were asked to sign a formal consent form notifying them that they were participating in a research study and explaining how the information collected would be used in accordance with the University of Kansas's Human Subject's Committee guidelines (see Appendix III).

After completing the demographic portion of the survey, visitors were asked if they would like to participate in a follow-up survey to be sent three months after the completion of data collection. If visitors agreed to complete the follow-up survey, contact information was obtained. Four months after the completion of the initial survey, the follow-up survey was sent to the self-selected participants. The survey was distributed either via email or US Postal Service mail, depending on the type of contact information obtained. A letter of introduction was sent to each participant, explaining how their information was obtained and reminding them of their prior willingness to participate in the follow-up study (Appendix IV).

The follow-up survey was much shorter in length than the initial survey (Appendix II). Questions regarding the use of the exhibit stations were dropped as they were deemed ineffective for further analysis (see Chapter 4). Instead, this survey focused on how much the visitors remembered manipulating the exhibit stations (6 items), whether they guided someone through the exhibit and read the signage (2 items), and with whom they talked about the exhibit during their visit (3 items). These items were identical to the items used in the Interaction portion of the initial survey. Fewer attitude questions were also used. As in the previous survey, the questions used a 5-point Likert scale, where a value of 1 indicates "not at all" or "mostly disagree" in the case of the attitude questions, 3 " somewhat" and "neutral", and 5 "a lot" or "mostly agree." Three open-ended questions were also included to determine the kind of impact the exhibit was having on the visitors.

Educational Staff Survey

The educational staff survey, the shortest of the three surveys conducted, contained 24 items written in a manner similar to the two visitor surveys (see Appendix II). Similar to the visitor surveys, the Staff Survey begins with questions related to what the staff feels that visitors do in the exhibit: seven items relate to identifying stations with which the visitors commonly interact, two items regarding whether staff felt visitors talked about the exhibit, and four items relating to whether visitors read the signage. The second half of the survey focused on the staff's attitudes toward the exhibit content and science (ten items). All questions in these two sections were 5-point Likert scale items with 1 indicating "mostly disagree," 3 "neutral" and 5 "mostly agree."

The final three questions asked for the staff's comments on their understanding of the nature of science, the scientific knowledge visitors should gain from the exhibits, and the purpose of the *Astronaut Training Center*. These questions were meant to be compared with responses from the visitors as to what they got out of their visit to determine if the intended purpose of the exhibit matched the outcomes seen by the visitors.

Visitor Behavior Analysis

To lend additional validity to the survey data, a rubric was developed to describe visitor behavior within the *Astronaut Training Center* exhibit (see Appendix VI). Visitors tracked with the rubric were not asked to participate in the visitor survey. A sign was posted at the entrance to the exhibit notifying groups that observational research was being conducted and that if visitors chose not to be tracked, they should notify the researcher. This was done to limit the influence of the researcher being present within the environment on how visitors interacted with the exhibits. Groups were selected at random as they entered the exhibit and followed while they were within the exhibit. A number was assigned to each group tracked using the rubric and the duration of their visit and the time of day recorded. A short description of the visiting group was compiled based on observation, including the number of adults and children, their gender and ethnicity. The approximate age of group members was also recorded, as well as the composition of the group (family, friends, or school).

The rubric related behavior seen in visitors with an associated behavior relating to learning: passive learning, active learning, and attention. The criteria for visitor behavior were: behavior (pointing, reading, or following the exhibit sequence), conversation (calls someone over, expresses a like or dislike, and non-exhibit related behaviors), and interactions (asks questions, manipulates exhibit, and watches another visitor interact). Visitor learning behaviors that were deemed to be in the form of attention toward the station were pointing to a station, calling another visitor over to the station, and asking a question. Learning behaviors associated with active learning were reading signage, expressing a like or dislike, and manipulating an exhibit station. Passive learning behaviors included following the exhibit sequence, non-exhibit related behaviors, and watching other visitors interact with exhibit stations. Observations were coded as to whether an adult or child was manipulating various exhibit stations.

Data Analysis

Data analysis was conducted using SPSS version 12.0, 14.0, and 15.0 for Windows. The mean response for the Likert scale questions were compared using a *t*-test for differences and two-tailed Pearson correlation coefficients to determine if a relationship exists between perceived learning, behavior, and attitude toward science and astronauts. Correlations were deemed significant at the $p \leq 0.05$ level, with an effect size of 0.25 and power of 0.70 (Shavelson, 1996). The open-ended questions were scored using the Learning Levels rubric, based on the model designed by Borun, Chambers, and Cleghorn (1996) and applied in Borun, Chambers, Dritsas, and Johnson (1997). A Factor Analysis was conducted on the attitudinal questions to determine if relationships exist between responses to these questions, resulting in identifiable underlying factors. Cronbach's alpha was then used to determine the reliability of the identified underlying factors.

Summary

A multi-method design was used to determine how visitors interacted with the *Astronaut Training Center* exhibit. This used an initial visitor survey to determine how visitors perceived they interacted with the exhibit stations and their attitudes toward science and space. A follow-up survey was given to volunteers a few months after the completion of the initial visitor survey to determine if visitors' perceptions of their behavior and attitudes toward space and science changed over time. A survey was also given to the educational staff at Science City to determine how their perceptions of visitor interactions related to what the visitors reported. As a check of reliability, a behavior rubric was used to observe visitor interactions within the exhibit. In the following chapter, the results of the initial visitor survey are reported.

Chapter 4

Initial Visitor Survey

This chapter reports on the first of two surveys of visitors to Science City's *Astronaut Training Center* in regards to their perceptions of learning about space and science, level of interaction with the exhibit, and their attitudes toward space, science and learning. The study uses visitor surveys to collect qualitative and quantitative data about the visitors' interactions. The survey was divided into three sections, the results of which are discussed here: visitor demographics, interactions with the exhibit (manipulating, interaction, reading, and socializing), and visitor attitudes toward space and science.

<u>Survey Collection</u>

Visitors to the *Astronaut Training Center* at Science City were asked to participate in a research survey regarding their experiences within the exhibit. Each participant was asked to sign a consent form as appropriate for adults or parents of minor children, following the recommendations of the University of Kansas – Lawrence Campus Human Subjects Committee (see Appendix III). Of the 172 people asked to participate in the survey, one hundred surveys were collected, a 42% refusal rate. All returned surveys were completed at the table setup outside of the *Astronaut Training Center*. Data collection lasted from January to December of 2004. From the original one hundred surveys collected, participants in the follow-up survey were obtained. The results of this survey are discussed in Chapter 5.

Survey Sample and Demographics

Of the one hundred initial visitor surveys collected, eighty percent of participants were over the age of 18. The majority were relatively well-educated female Caucasians and 70% had at least some college experience (Figure 4.1 and 4.2). Of those with college degrees, most had a major in either Liberal Arts or Science and Engineering. The vast majority came with family groups from households with incomes ranging from \$50,000 to \$74,900 (Figure 4.3 and 4.4).

The sample was compared with the visiting population to Union Station (Blue Water Consulting Inc., 2002) in terms of gender and ethnicity using a Chi-squared analysis (Table 3.1). At the $p \leq 0.05$ level, the two samples were determined to be statistically the same for both the gender and ethnicity variables, Chi-squared = 0.001, $p = 0.971$ and Chi-squared = 8.632, $p = 0.071$, respectively. This indicates that the study's sample is reflective of the general visiting audience at Union Station.

Figure 4.1 Gender and Ethnicity of Initial Visitor Sample

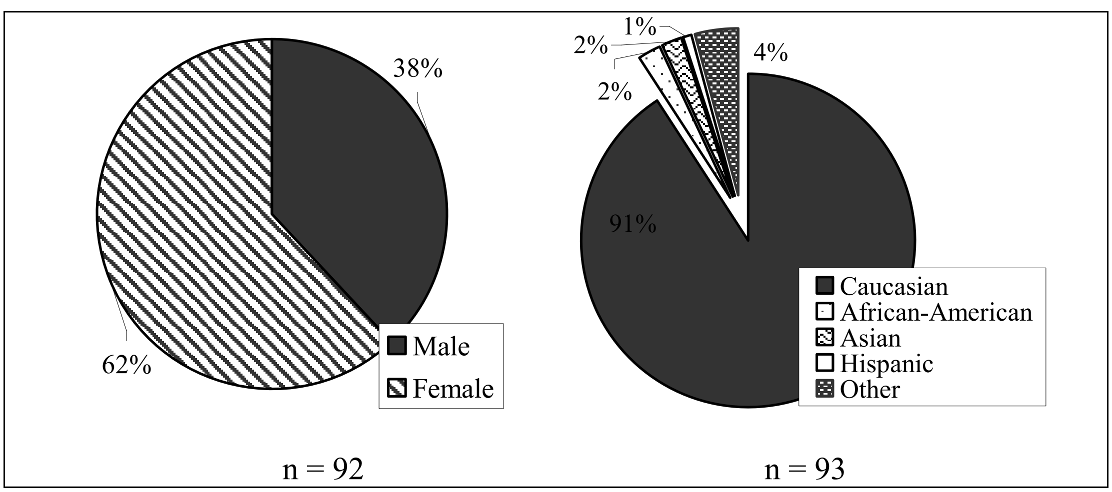


Figure 4.2: Level of Education and College Major

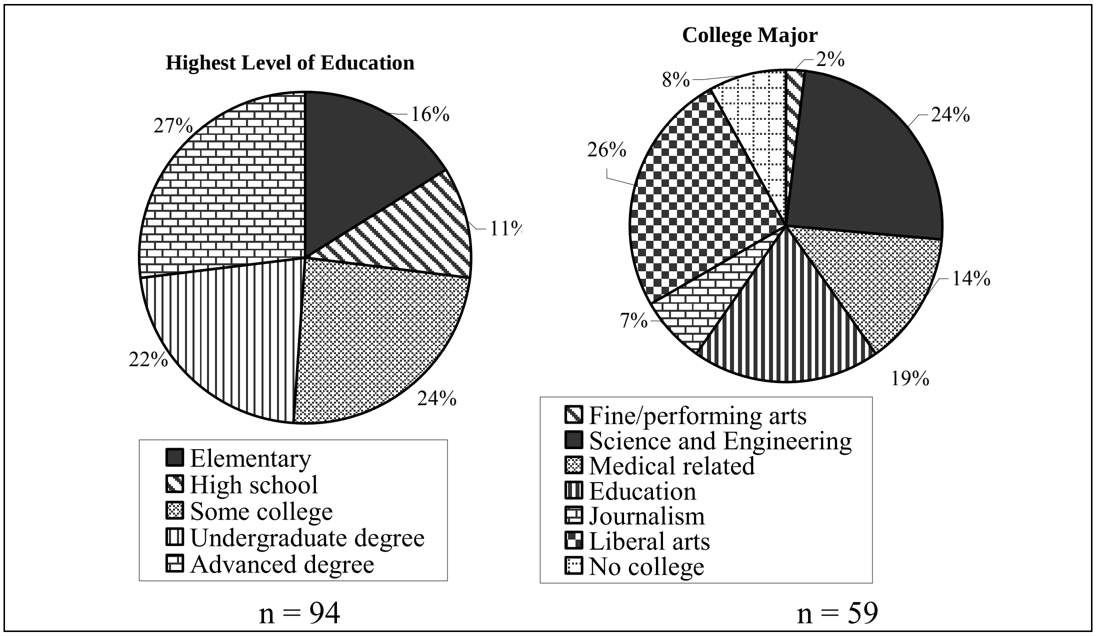
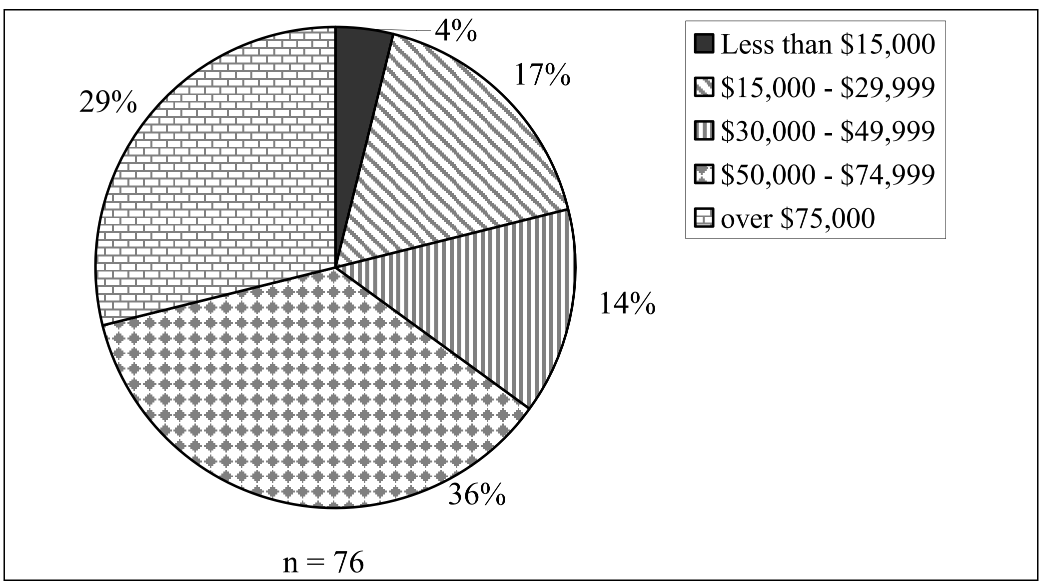


Figure 4.3: Household Income



The vast majority of visitors participating in the survey were at Science City as part of a family group consisting of three to four members (Figure 4.4). Seventy-six percent of participants came with children, generally one or two in each group and between the age of nine and eleven (Figure 4.5). Thirty-two percent of the participants had visited Science City previously. Of those who had been before, 52% had been once or twice (Figure 4.6). Reasons for their visit included: wanting to see Science City (23%), wanting to do something educational with the kids (21%), bringing or are out-of-town company (16%), recommendation by friends (11%), reading about it in a newspaper, magazine (11%), or for other reasons (5%). No one responded that they decided to visit based on a TV or radio advertisement. Reasons for visiting and the make-up of the social group reflected those found in previous research (Falk, 1998; Falk et al., 1998; Hood, 1983; Prentice, Davies, & Beeho, 1997).

Figure 4.4: Social Group and Number of Previous Visits to Science City

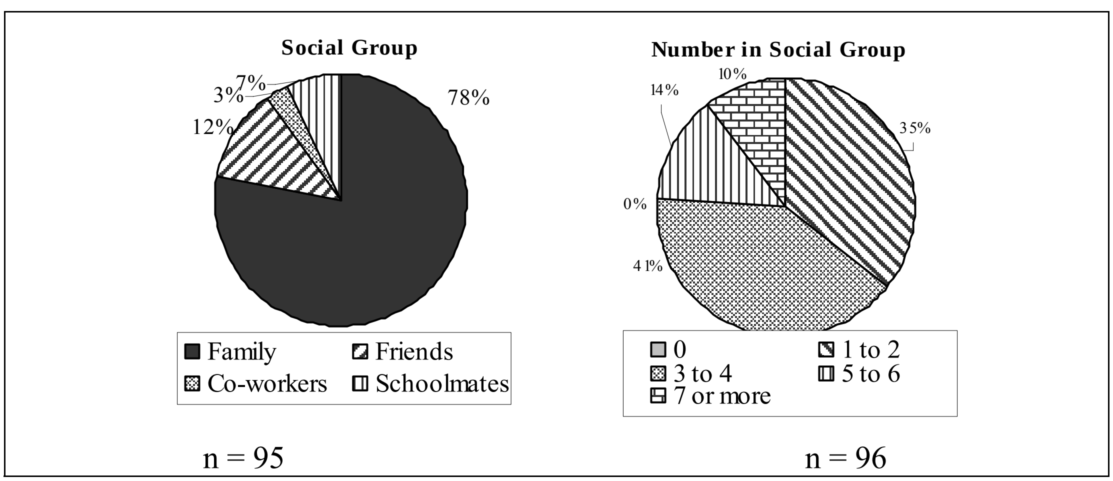


Figure 4.5: Percentage of Children in Social Groups and Their Ages

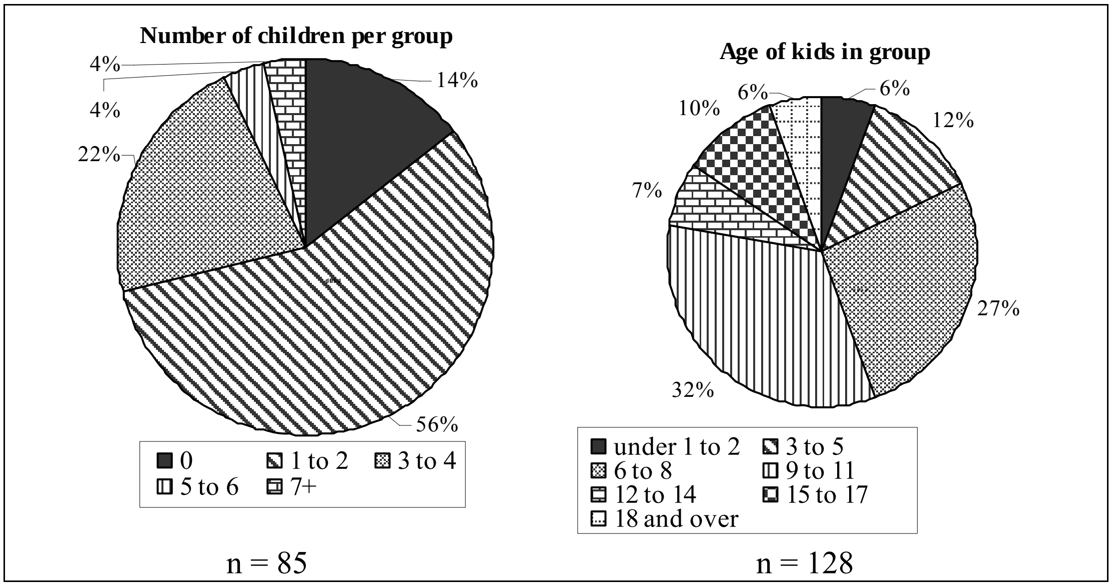
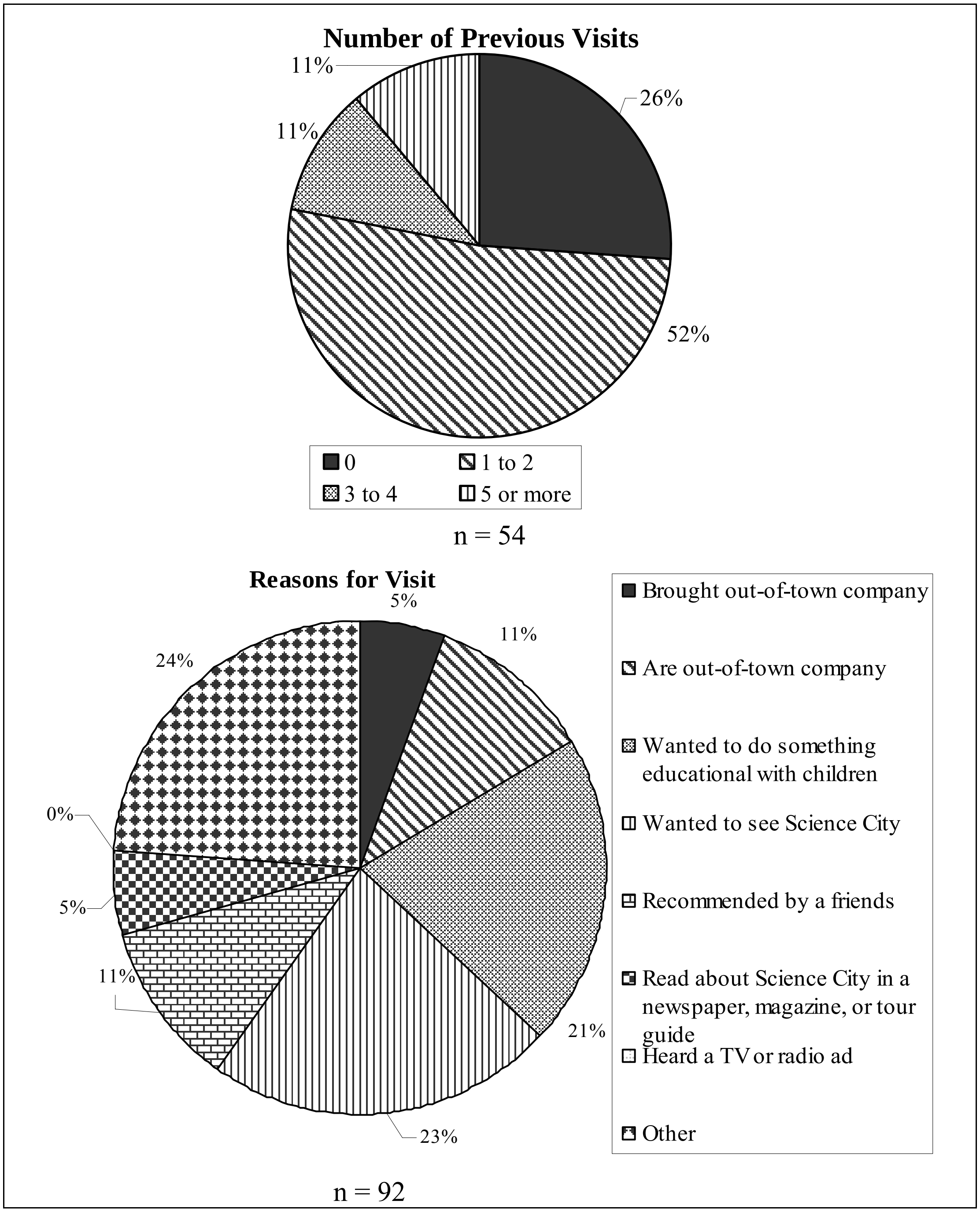


Figure 4.6: Number of Previous Visits and Reasons for Visit



Perceived Visitor Behavior and Factor Analysis

Manipulating and Interacting

Visitors were asked how much they manipulated each exhibit station in the *Astronaut Training Center*. Mean values are shown in Figure 4.7. Generally, visitors felt they manipulated the Shuttle Approach Simulator more than any other station, t (96) = 2.56, p = 0.01. This is not surprising, as it was not unusual to see a line forming around the arcade/game-like exhibit station. Of the stations surveyed, the Mars Soil Test was found to have been manipulated the least, t (91) = -2.58, p = 0.01. This may be due to its slow response of the display. Research by Falk(1982a) shows a substantial number of visitors are looking for an immediate and clear response from an exhibit station and will quickly move on if it is not received. While this station does offer a response in the form of identifying properties of the Martian soil, the slowness of response may cause the visitors to move on without engaging in the station.

Mean visitor use of exhibits stations was also found (Figure 4.7). Generally, again, visitors used the Shuttle Approach Simulator more than any other exhibit, t (94) = 2.01, p = 0.05. Visitors rated manipulating the stations more than how much they indicated using them, with one exception, the Mars Soil Test, where usage was rated higher than manipulation. In the case of usage, the Fitness Test was found to have the lowest average level of manipulation. This lower value may be due to the lack of variables to manipulate at the station, as a visitor needs to only sit on the bicycle and begin to peddle to have their heart rate measured. This idea was not

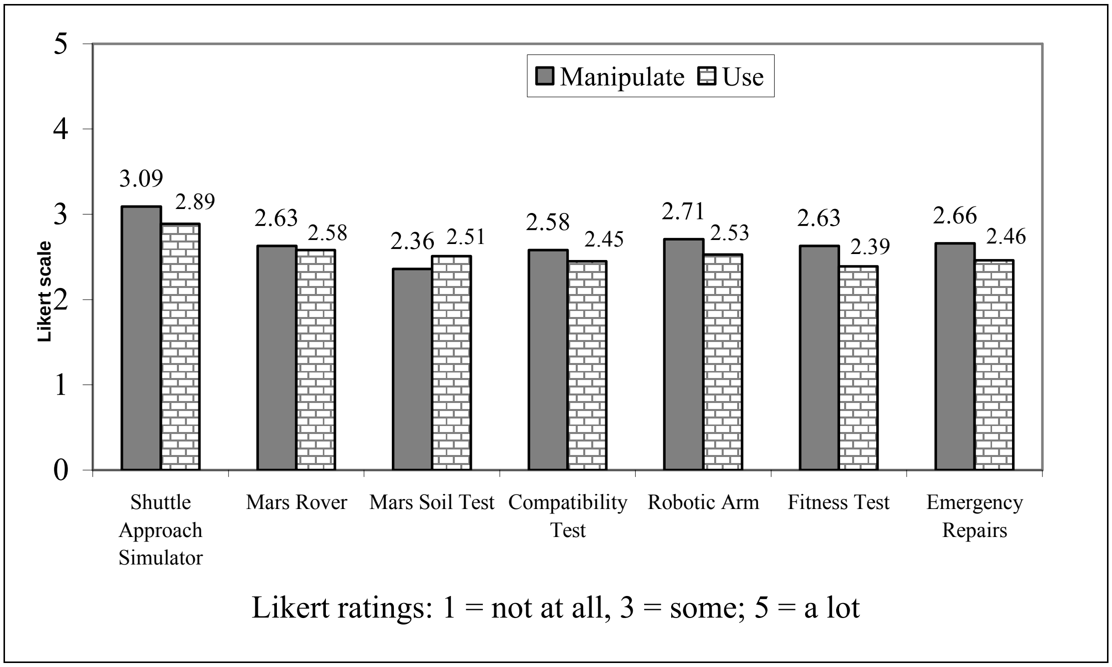


Figure 4.7: Mean Visitor Response for Manipulating and Using Exhibit Stations

explored further in the follow-up survey.

Similar means were generated for each of the stations surveyed. During the data collection period, concerns over how differently visitors understood the first two questions in the survey: “did you manipulate (x station)”, “did you (do something at the station)” arose. A number of visitors questioned the difference between what manipulate (passive use) and interaction (active, minds-on use) of stations referred, even after listening to the researcher’s explanation. To test the hypothesis that visitor responses to both questions were similar, a *t*-test for difference was conducted between responses given for the two Likert questions. At the $p \leq 0.05$ level, the null hypothesis that there is no statistically significant difference between the responses was accepted for all but two of the station pairs (Table 4.1). The two stations that

Table 4.1: *t* Test For Differences Between Visitor Perception of Manipulation and Interaction With Exhibit Stations

Pair	Station	Interaction	n	M	SD	*t*	*df*	*P*
1	Shuttle Approach Simulator	Manipulation	97	3.09	1.48	2.497	92	0.0143
	Use Shuttle Approach Simulator	Interaction	95	2.89	1.53			
2	Mars Rover	Manipulation	96	2.63	1.38	0.269	91	0.7884
	Drive the Mars Rover	Interaction	93	2.58	1.44			
3	Mars Soil Test	Manipulation	92	2.36	1.31	-1.79	87	0.0771
	Examine Mars Soil Test	Interaction	92	2.51	1.35			
4	"Compatibility Test"	Manipulation	95	2.58	1.48	0.838	90	0.4044
	Work with someone to "center the Earth"	Interaction	95	2.45	1.60			
5	Robotic Arm	Manipulation	92	2.71	1.56	1.043	87	0.2998
	Drive Robotic Arm	Interaction	90	2.53	1.52			
6	Astronaut Fitness Test	Manipulation	93	2.63	1.40	2.462	87	0.0158
	Take Astronaut Fitness Test	Interaction	93	2.39	1.35			
7	"Emergency Repairs" knobs	Manipulation	91	2.66	1.45	1.149	86	0.2537
	Make "Emergency Repairs"	Interaction	93	2.46	1.46			
8	Read signage		94	3.55	1.28	1.915	87	0.0588
	Read explanatory labels		94	3.31	1.33			

See also Figure 4.7.

tested statistically significant, the Shuttle Approach Simulator and the Fitness Test, give visitors immediate feedback about their interactions on a personal level, whether in the form of a crashing space shuttle or the individual's heart rate as he or she peddles the bicycle. This feedback may cause visitors to feel more engaged with the station and allow visitors to better distinguish between their manipulation of the exhibit versus use and interaction with the station, these responses being in the form of, "I can land the shuttle!" or "I can get my heart rate higher!"

Reading and Socializing

As part of their experience at Science City, 88% of visitors to the *Astronaut Training Center* reported reading the explanatory signage and 94.4% reported performing the tasks indicated by the signage. A statistically significant correlation exists between reading the signage and doing what the signage said, r (85) = 0.224, $p = 0.039$, on individual question items. Ninety-seven percent of respondents indicated that they felt the signage was helpful and a correlation existed between reading the signage and finding the signage helpful, r (81) = 0.487, $p \leq 0.01$, and doing what the signage said and finding them helpful, r (84) = 0.291, $p = 0.007$. Statistical analysis also showed that no correlation exists between perceived learning and reading or following the signage posted at the exhibit stations. So, while the signage does not appear to have an effect on visitor perceived learning, the signs do affect visitor behavior at exhibit stations. Visitors find guidance from the signs about how to use the exhibit that they did not find apparent when they initially tried to interact with the exhibit.

Table 4.2: Visitor Response to Questions Regarding Reading the Signage

	N	Percentage	
		Yes	No
Did you read the signs next to the station?	94	88.3	11.7
Did you do what the signs said?	89	94.4	5.6
Did you find the signs helpful when playing with the exhibit?	86	97.7	2.3
Did the signs answer your questions about this exhibit?	87	90.0	10.0
Would you like a resource that helps you find out more information?	32	56.3	44.7
If so, what kind of resource? (number of responses) Booklet 6 Website 4 Signs 6 Other 5	21		

When asked if the signage answered questions visitors had about the exhibits, 89% of visitors surveyed indicated that the signage did help. Visitors' responses to finding the signs helpful correlated strongly with visitors who felt their questions were answered within the signage, $r\ (84) = 0.425$, $p \leq 0.01$. This suggests that visitors find value in reading the signs and may need the signs to figure out what to do at the stations. This adds further support to the need for appropriate signage around the exhibit stations that describe what visitors should do.

When asked if an additional resource about the exhibit would be helpful, 56% responded in affirmative. Twenty-eight percent of visitors indicated that signs would be helpful and another 28% indicated a booklet. In both cases, these resources are available at the exhibit, in the form of the signs previously discussed, and a booklet entitled "I want to be an ASTRONAUT! Science City Astronaut Training Program." This booklet incorporates the theme of becoming an astronaut into other exhibits at Science City to see if visitors have the right stuff to become future astronauts. It is not clear if these visitors overlooked these materials or felt they needed to be more detailed. Other responses included the need for more visible instructions, more audio recordings, and explanations for specific exhibit stations.

From a constructivist standpoint, talking about experiences helps individuals to construct knowledge better, as they work to explain their ideas to others (Bodner et al., 2001). Visitors to the *Astronaut Training Center* also participated in activities that involve developing shared meaning across group members. Sixty-three percent of respondents indicated that they interacted with the exhibit by talking about the exhibit (marking a 4 or 5 to indicate "a lot"), although 46% indicated that this interaction was with people in their group or family, 12% with other visitors, and 7% with Science City facilitators. It should be noted that Science City facilitators were not assigned to the *Astronaut Training Center* and that any interactions between the visitor and facilitators while in the exhibit would be done at random, as the facilitators pass through the exhibit on their way to the lower level of Science City. Twenty-eight percent of respondents reported having guided another visitor through the exhibit. While this question was aimed at seeing how many previous visitors (whether on school trips or family visits) come back to show friends Science City and the *Astronaut Training Center,* the responses may be indicative of parents bringing young children or individuals bringing out-of-town company as the percent of responses generally match when compared with Figure 4.6.

Visitor Perception of Learning

Eighty-six percent of visitors to the *Astronaut Training Center* felt they had learned something from the exhibit. Visitors' perception of learning while in the exhibit was explored using open-ended questions to determine how visitors interpreted the exhibit and linked it with prior knowledge. The fewest responses were recorded for these questions, due to the open-ended nature of the questions requiring more time per question from the visitor. Of those who did respond, the vast majority used one-word responses. Forty-one percent of visitors were able to describe their learning at the identifying level as described by Borun, Chambers, Dritsas, and Johnson(1997) (Table 4.2). Visitors described what they learned with statements such as "dizziness with out *[gravity]*," "Mars info," "about life on the shuttle," and "more about all space concerns." Statements using a more descriptive approach included, "the bathroom was cool," and "driving the rover was hard to handle." One visitor interpreted his/her visit by writing, "Life in space is very different than life on land. It is very interesting how astronauts get to live inside the shuttle. It must be very challenging to grasp a new set of *[coordination]* skills in space."

When asked what visitors felt the exhibit was trying to show, 45% described aspects of the exhibit, such as "life in space" and "life as an astronaut" (Table 4.2). Other visitors described their experiences with statements such as a "brief view of what a space trip would be like" and "different aspects of the space program from mars to the shuttle." One visitor was more specific, stating: "I learned about what the food looks like in the shuttle. I also learned that it takes a lot of skill to land the

Table 4.3: Percentage of Respondents For Each Learning Level

	N	Percentage		
		Identify	Describe	Interpret and Apply
Describe what you learned from the exhibit.	39	41	38	21
What do you think the exhibit is trying to show?	53	45	43	11
What comes to mind when you think about this exhibit?	47	74	21	4

shuttle." These responses lacked links to experiences outside of the exhibit. Visitors whose responses were deemed to be interpreting and applying made stronger references to personal experiences and experience outside of the *Astronaut Training Center*. One visitor wrote that the exhibit was trying to show "how men (or women) *[parenthesis by visitor]* live and work up there. And that it's not as boring as it looks."

When asked what came to mind when thinking about the exhibit visitors had just been through, the majority of respondents (74%) wrote comments that were space related, for example, "NASA," "Space," and "Astronauts." Ten specific examples of stations in the *Astronaut Training Center* exhibit were given, including references to its interactivity. Eight visitors described the exhibit as "fun" while three more identified it as being "challenging." One visitor described the exhibit using the cliché, "space the final frontier." Two individuals responded in an interpreting and applying manner to the question, stating "the current Mars Rover mission," in reference to the NASA's Mars Exploration Rover Mission with rovers Spirit and Opportunity, and "great fun for kids!" This question, more than either of the other two, elicited more single-word responses. These responses captured major, public-oriented space ventures. Media coverage has focused on NASA's space flights and development programs, resulting in a bias of responses reflecting NASA's presence in space missions.

Factor Analysis

When designing the initial visitor survey, the behavior questions were divided among four areas of interest: (1) manipulating, and (2) interacting with the exhibit stations, (3) talking and (4) reading about the exhibit stations. The interacting and manipulating questions referred to specific exhibit stations, while the talking and reading questions were more general in nature, pertaining to the exhibit as a whole. To establish a relationship between questions in these categories, a factor analysis was performed on the 24 interaction questions, combining the manipulation and interaction questions, using the maximum likelihood method. Factor analysis is "used to identify factors that statistically explain the variance and covariance seen among measures" (Green & Salkind, 2003) By grouping variables in which visitor responses are similar, the analysis identifies underlying constructs that may explain patterns of responses. The factors can then be controlled in future studies by the choice of measures and research participants.

Statically, the process involves two steps: factor extraction and factor rotation. Factor extraction identifies the number of factors underlying a set of measured variables. Factors are extracted using a correlation matrix, typically in the form of a principal components analysis. The first extracted factor accounts for most of the variability (or eigenvalue) among the measures, the second factor accounted for the second most variability, and so on. Two statistical criteria are then used to determine the number of factors to extract: the absolute magnitude of the eigenvalue and the relative magnitudes of the eigenvalues or a scree test. *A priori* conceptual beliefs regarding the number of underlying factors can also influence the results of these tests, based on the selected number of factors to retain in the second step. Next, factor rotation statistically manipulates the results to make the factors more easily interpretable and allows the researcher to make a final decision on the number of underlying factors. Rotated factors may be uncorrelated (orthogonal) or correlated (oblique). The most popular method, Varimax, yields uncorrelated factors. Factors are then typically named by examining the largest values linking the factors to measures in the rotated matrix.

Three criteria were used to determine the number of factors to use in the rotation: the *a priori* hypothesis that the measure was multidimensional (following the four areas of interest within the survey; (1) manipulating, and (2) interacting with the exhibit stations, (3) talking and (4) reading about the exhibit stations), the scree test, and the interpretability of the factor solution. Analysis of the scree plot for the sharpest decent in eigenvalue before the plateau region, indicated seven dimensions involved, accounting for 61% of the variance seen within the data and validating the initial hypothesis of having a multidimensional variable. Based on this plot, the seven categories were rotated using a Varimax rotation procedure. These factors were used to statistically identify questions for which visitors provided similar answers.

Cronbach's alpha was then produced to determine the reliability of the underlying factors.

The rotated solution, as shown in Table 4.4, yielded seven interpretable interaction factors:

- Communicating
- Video Game Stations
- Push-button Stations
- Talking with Others Outside the Group
- Eye-hand Coordination
- Astronaut Fitness Test
- Mars Soil Test

Questions were deemed to fall under a certain factor if the factor loading values were ±0.4 or greater. Questions with loadings less than 0.4 were not included in the categories. The first factor, Communication, emphasized communication among visitors within a group and between the exhibit and the visitors via reading exhibit signage. This factor accounted for 11% of the total variance. The Video Game Stations factor incorporated two stations that had the feel of a video game, the Mars Rover and the Shuttle Approach Simulator. Both featured a joy stick and asked visitors to manipulate an object according to the directions on the screen to accomplish either landing the space shuttle, or moving the Mars Rover. This factor accounted for 10% of the total variance. The third identified factor, Push-button Stations, combined two exhibit stations, the Emergency Repairs and satellite orbiter.

Table 4.4: Factor Analysis of Visitor Interaction Questions on Initial Visitor Survey

Item	Attitude Statements	Factors Ranked by Loading Magnitude						
		1	2	3	4	5	6	7
Communicating								
1bi	Talked about the exhibit	0.93	-0.11	0.01	0.13	-0.07	0.06	0.22
1bii	Talked with people in group or family	0.58	-0.14	0.03	0.15	0.05	0.03	0.16
1d	Read signage	0.56	0.10	0.10	0.25	-0.07	-0.05	-0.00
2k	Read explanatory labels	0.48	0.12	0.21	0.16	0.11	0.25	-0.08
1aiv	"Compatibility Test"	0.41	0.15	0.14	-0.05	0.21	0.04	0.03
2d	Work with someone to "center the Earth"	0.42	0.17	0.24	-0.12	0.06	0.12	-0.09
Video Game Stations								
1ai	Shuttle Approach Simulator	0.13	0.91	0.14	0.05	0.04	0.11	0.09
2a	Use Shuttle Approach Simulator	0.23	0.81	0.10	0.02	0.16	0.07	0.07
2b	Drive Mars Rover	-0.10	0.51	0.09	0.06	-0.09	0.12	0.04
1aii	Mars Rover	-0.04	0.43	-0.02	0.07	0.07	0.12	0.28
Push-button Stations								
2i	Make "Emergency Repairs"	0.19	0.06	0.96	0.13	0.00	0.13	0.05
1avii	"Emergency Repairs" knobs	0.11	0.26	0.75	0.10	0.08	0.13	0.17
2h	Examine satellite orbit simulator	0.32	-0.01	0.53	0.27	0.22	0.17	-0.04
Talking with Others Outside the Group								
1biii	Talked with other visitors	0.07	-0.00	0.15	0.83	0.08	0.10	0.08
1biv	Talked with Science city facilitators	0.04	0.11	0.10	0.83	-0.04	0.08	0.08
1c	Guided someone through the exhibit	0.22	0.03	0.01	0.51	0.07	-0.08	0.08
Eye-hand Coordination								
1av	Robotic Arm	-0.03	0.04	0.06	0.08	0.94	0.11	0.17
2f	Drive Robotic Arm	0.12	-0.02	0.05	0.08	0.79	0.18	0.09

Item	Attitude Statements	Factors Ranked by Loading Magnitude						
		1	2	3	4	5	6	7
Astronaut Fitness Test								
2g	Take Astronaut Fitness Test	0.14	0.19	0.25	0.03	0.15	0.92	0.10
1avi	Astronaut fitness	0.10	0.28	0.12	0.11	0.30	0.73	0.08
Mars Soil Test								
1aiii	Mars Soil Test	0.19	0.10	0.04	0.11	0.09	-0.01	0.97
2c	Examine Mars Soil Test	0.04	0.23	0.10	0.10	0.13	0.10	0.71
*item 1 denotes manipulate questions, item 2 denotes interaction questions.								

These stations asked visitors to push buttons to receive a response and did not require much additional thought from the visitors. This factor accounts for 9% of the variance. The fourth factor, Talking with Others Outside the Group, brings together questions regarding talking about the exhibit with other people, the Science City facilitators, and guiding someone through the exhibit, accounting for 9% of the total variance. The fifth factor, Eye-hand Coordination, focuses on the Robotic Arm. This station requires manual dexterity to manipulate it, but did not have the video game quality as the Shuttle Approach Simulator and Mars Rover. The Robotic Arm station asks visitors to drop a ping-pong ball through a small hoop attached to the wall of the station. Visitors must use a combination of movements; horizontal, vertical, up/down, and axis rotation, that will result in the desired effect. This factor accounted for 8% of the total variance. The final two factors relate to individual exhibit stations, the Fitness test and the Mars Soil Test. Each accounted for 7% of the total variance.

Cronbach's alpha is a measure of reliability that measures the consistency of an individual's performance item to item across a single form, based on the standard deviation of the test and standard deviations of the items. Cronbach's alpha coefficient was computed for the seven factors identified in the factor analysis. The means, variance, and alpha values are shown in Table 4.5. For studies of this nature, values of 0.6 or larger are considered to have high reliability. The coefficient was 0.7 or above for all factors, indicating that the internal consistency of responses was very high.

Table 4.5: Cronbach's Alpha of Reliability for Interaction Factors

Factor	α	N	M	Variance
Communication	0.762	6	3.144	0.266
Video Game Stations	0.801	4	2.823	0.078
Push-button Stations	0.842	3	2.513	0.003
Talking with Others Outside the Group	0.759	3	1.775	0.079
Eye-hand Coordination	0.877	2	2.625	0.006
Astronaut Fitness Test	0.901	2	2.472	0.023
Mars Soil Test	0.854	1	2.466	0.017

Correlations with Visitor Demographics

The mean visitor response for the seven identified interaction factors were correlated to visitor demographics, such as reason for visit, previous visit, number of individuals and children in group, level of education, college major, annual household income, ethnicity, and gender, using a two-tailed Pearson correlation coefficient. No statistically significant correlation was found among the items. Single items were also compared, the results of which are discussed below.

Manipulating Single item

Using the manipulation single items, correlations with demographic variables were explored. The level of education was found to correlate moderately negative with manipulating specific exhibit stations such as the Shuttle Approach Simulator, r (90) = -0.230, p = 0.028, Astronaut Fitness Test, r (87) = -0.267, p = 0.012, and "Emergency Repairs," r (85) = -0.284, p = 0.008. This suggests that younger visitors, those whose educational level is lower, manipulated these stations more than visitors with higher levels of education.

Other demographic variables also correlated with the manipulating questions, adding support to the idea that higher levels of interaction occur with younger visitors. College major correlated with manipulating the Mars Rover, r (55) = 0.363, p = 0.006, such that as the level of manipulation was slightly higher, college major moved away from within the sciences to individuals not sure of their major or not having a major. This suggests that the Mars Rover is appealing to individuals without a science background and adds credence to the idea that younger visitors, as indicated by level of education, manipulate the exhibit stations more than older ones (no college major and no college experience being the last choice in the list of college majors, see Appendix II).

Manipulating the Compatibility Test correlated with annual household income, r (72) = 0.248, p = 0.035. It is possible that visitors with higher levels of income have a deeper understanding of the importance of controlling their heart rate while exercising, i.e. a deeper understanding of their health as a result of higher levels of fitness education or education in general. This idea is supported by work done by Kutner, Greenberg, Jin, and Paulsen (2006). They found that starting with individuals who had completed high school or obtained a GED, the average health literacy increased with higher education obtainment. They also found that adults living below the poverty level had lower average health literacy than adults living above the poverty level.

Reading/Socializing Single Item

Relationships were also found between two interaction questions and some of the demographic variables. Talking about the exhibit with the family or group correlated with level of education, r (80) = 0.254, p = 0.022. This suggests that individuals with higher levels of education felt more comfortable discussing the exhibit with others in the group, possibly due to feeling more comfortable with material presented in the exhibit or more willing to share the discovery of new information when they did not understand the exhibit. Talking about the exhibit with other visitors correlated with both having visited previously, r (59) = 0.300, p = 0.02, and household income, r (59) = -0.325, p = 0.011. Again, the visitors' comfort level with the information presented in the exhibit may play a role in how they rated talking about the exhibit with individuals outside of their group. Visitor's who had previously visited could offer their prior experience with the exhibit to other individuals to suggest which stations to interact with or how to best interact. Household income is typically a function of level of education, so that as previously stated, visitors with higher levels of education, and therefore higher household incomes may feel more comfortable with the material presented in the exhibit or more comfortable admitting what they do not know and working with their children to find answers to their questions.

Inter-Factor Correlations and Correlations with Learning

The Pearson correlation coefficient was used to determine if a statistically significant correlation exists between the Interaction Factors and visitors' perception of learning. No statistically significant correlation was found at the $p \leq 0.05$ level. Some statistically significant correlations were found between the Interaction Factors (Table 4.6). For instance, the Communication factor correlated with Video Game Stations, r (98) = 0.256, p = 0.011, push-button exhibits, r (97) = 0.415, $p \leq 0.01$, talking with others outside the group, r (94) = 0.531, $p \leq 0.01$, and the Astronaut Fitness Test, r (97) = 0.275, p = 0.006. The Video Game Stations factor correlated with the push-button factor, r (97) = 0.236, p = 0.019, Talking with Others Outside the Group, r (94) = 0.216, p = 0.035, the Astronaut Fitness Test, r (97) = 0.381, $p \leq$ 0.01, and the Mars Soil Test, r (95) = 0.583, $p \leq 0.01$. The Push-button Exhibit factor correlated with Talking with Others Outside the Group, r (93) = 0.297, p = 0.004, and the Astronaut Fitness Test, r (96) = 0.448, $p \leq 0.01$. Talking with Others Outside the Group correlated with the Eye-hand coordination factor, r (91) = 0.225, p = 0.015, and the Mars Soil Test, r (92) = 0.215, p = 0.039.

The need to communicate with the visitor is evident in the correlations with the station oriented factors, such as the Mars Soil Test, Video Game Stations, and Push-Button stations, and the Communication factor. Visitors who answered positively toward using these stations typically indicated they read the signage and talked about the exhibit with other visitors within their group. Correlations were also seen between talking to visitors outside the individual's group and with Science City facilitators, r (71) = 0.728, $p \leq 0.01$.

Correlations between the Video Game Stations and push-button exhibits, the Astronaut Fitness Test and Mars Soil Test are expected, due complex nature of the exhibit stations requiring more explanation to use properly than other stations. The Eye-hand coordination factor correlated with the Astronaut Fitness Test and the Mars Soil Test. Both exhibits require some coordination to manipulate the station, whether for peddling a bicycle or moving a robot arm to a sample to run tests. Interacting with the Astronaut Fitness Test and the Mars Soil Test correlated significantly, r (95) = 0.219, p = 0.032.

Table 4.6: Correlation Between Visitor Perceived Learning and Interaction Factors

		Factor						
		1	2	3	4	5	6	7
Do you feel you learned anything from the exhibit?		0.052	0.099	-0.109	-0.069	-0.219	-0.046	0.023
Factor	1 Communication	1	0.256*	0.415**	0.531**	0.198	0.275**	0.178
	2 Video Game Stations		1	0.236*	0.216*	0.158	0.381**	0.583**
	3 Push-button			1	0.297**	0.147	0.448**	0.184
	4 Talking with Others Outside the Group				1	0.255*	0.135	0.215*
	5 Eye-hand coordination					1	0.337**	0.244*
	6 Astronaut Fitness Test						1	0.219*
	7 Mars Soil Test							1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed).

Visitor Attitude and Factor Analysis

Attitudes toward Learning, Science, and the Exhibit

Visitors to the *Astronaut Training Center* generally had positive attitudes toward science and learning. Mean responses to attitude questions are shown in Figures 4.8, 4.9, and 4.10. Seventy percent of visitors responded that they liked learning. Sixty-nine percent of visitors surveyed indicated that they liked science. Seventy percent of visitors also held positive attitudes toward watching educational science television. Fifty-four percent of respondents, when combining agree and mostly agree, like to read about science in a newspaper, while 20% responded neutrally. Sixty-one percent want to learn more about astronauts. Clearly, visitors

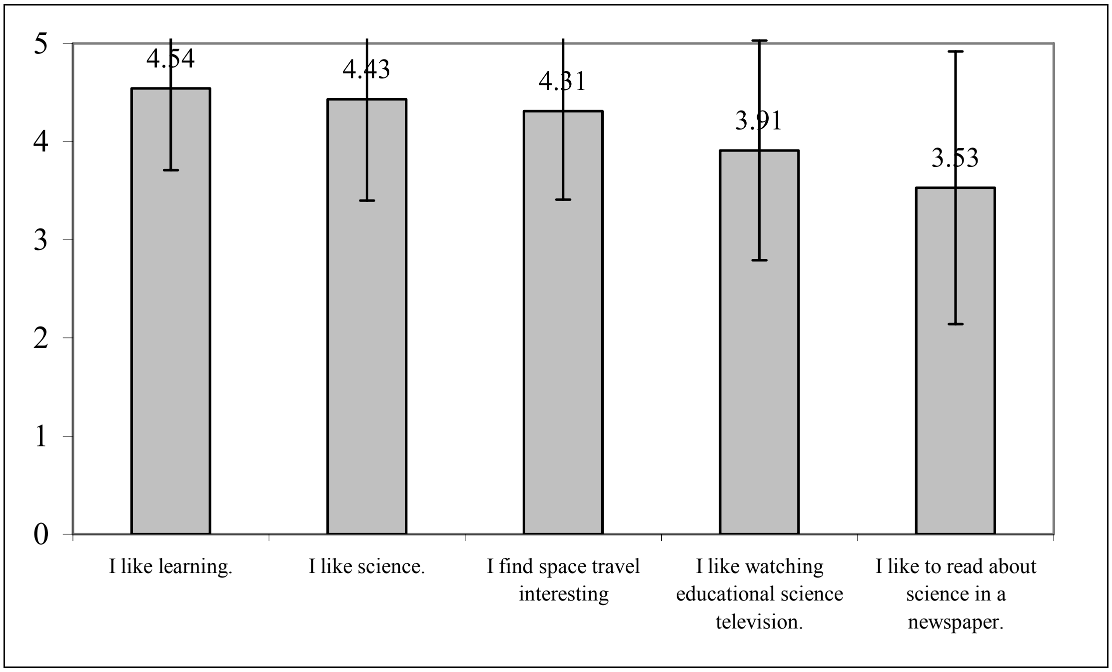


Figure 4.8: Mean Visitor Response for Attitudes Toward Learning

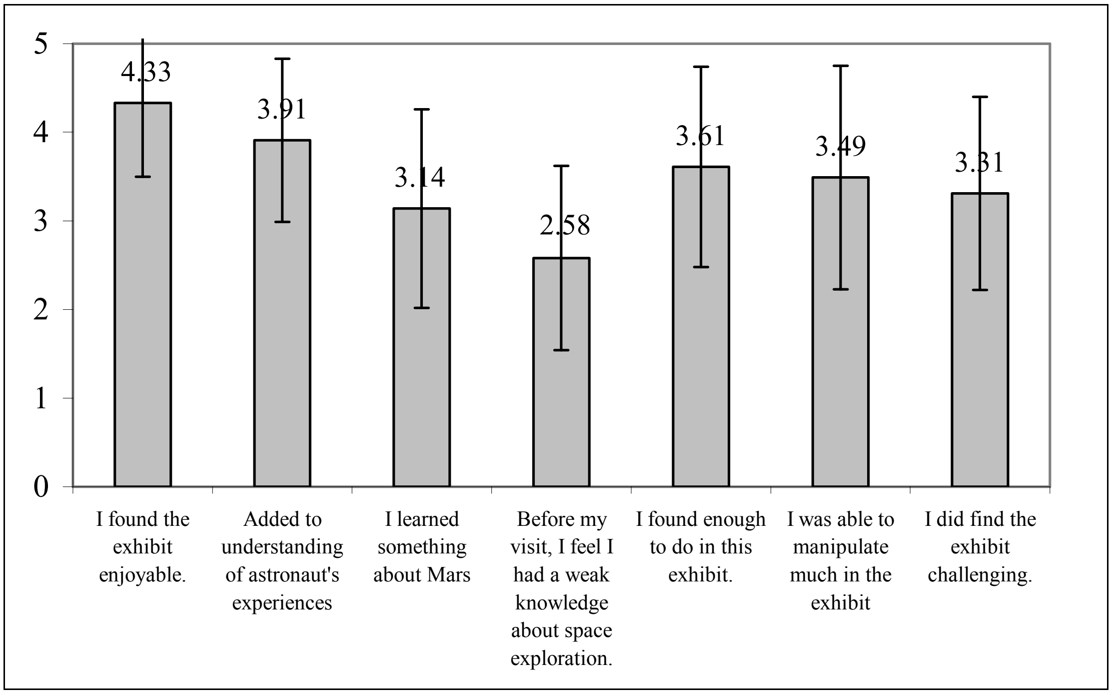


Figure 4.9: Mean Visitor Response for Attitudes Toward Interacting at the Exhibit

come to Science City with positive attitudes toward science and learning about science. These attitudes indicate that the visitors' understanding of science, especially chemistry, can potentially be expanded if the content is made personally relevant.

When asked about their attitudes toward the exhibit, 89% of respondents found the exhibit enjoyable. Seventy-one percent of visitors felt that the exhibit added to their understanding of an astronaut's experiences. Thirty-eight percent of visitors surveyed felt they had learned something about Mars, while 37% responded neutrally. Eighty-eight percent find space travel interesting. Sixteen percent indicated that they had a weak knowledge of space exploration, while 41% responded neutrally to the statement. This indicates that the exhibit is able to offer new knowledge regarding space travel to visitors of varying educational levels. When asked about their experiences in the exhibit, 57% of respondents felt there was enough to do in the exhibit. Seventy-two percent of visitors surveyed felt they manipulated many stations within the exhibit. Forty-two percent found the exhibit challenging. This suggests that not only did visitors find new knowledge within the exhibit, but they were also challenged at a level slightly above their level of ability. This level of enjoyment is often a key part in the feeling of flow (Csikszentmihalyi, 1988), a state of mind where the completion of a task involves a level of difficulty slightly above the ability of the individual, such that the individuals' concentration is focused in such a way that the passage of time becomes unnoticed.

Visitors also generally held positive attitudes toward the exhibit. Fifty-three percent of visitors felt the Living Quarters reflected their idea of life on a space shuttle. Forty percent felt that the Living Quarters exhibit could be more detailed. Thirty-one percent felt remotely operating the Mars Rover was not as exciting as watching the rover move, while twenty-eight percent disagreed. Sixteen percent responded neutrally to the statement. Eighty-one percent of visitors felt that life in a space shuttle is different from life on Earth and 6.66% felt that life on Mars is similar to life on Earth, while 74% disagreed with the statement.

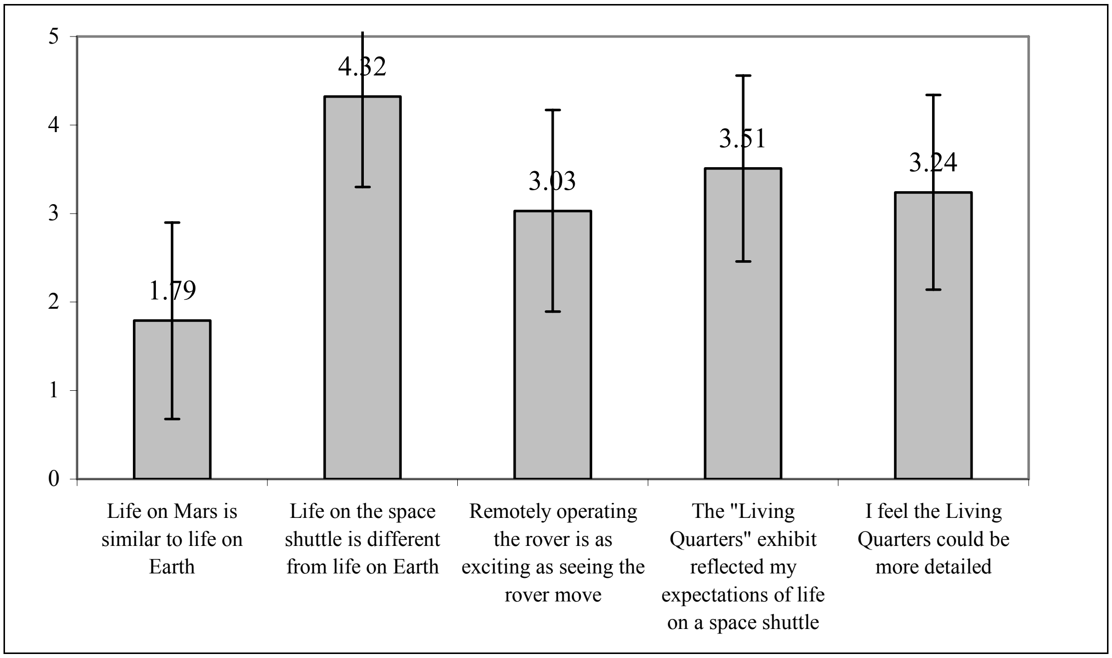


Figure 4.10: Mean Visitor Response for Attitudes Toward Space and Science

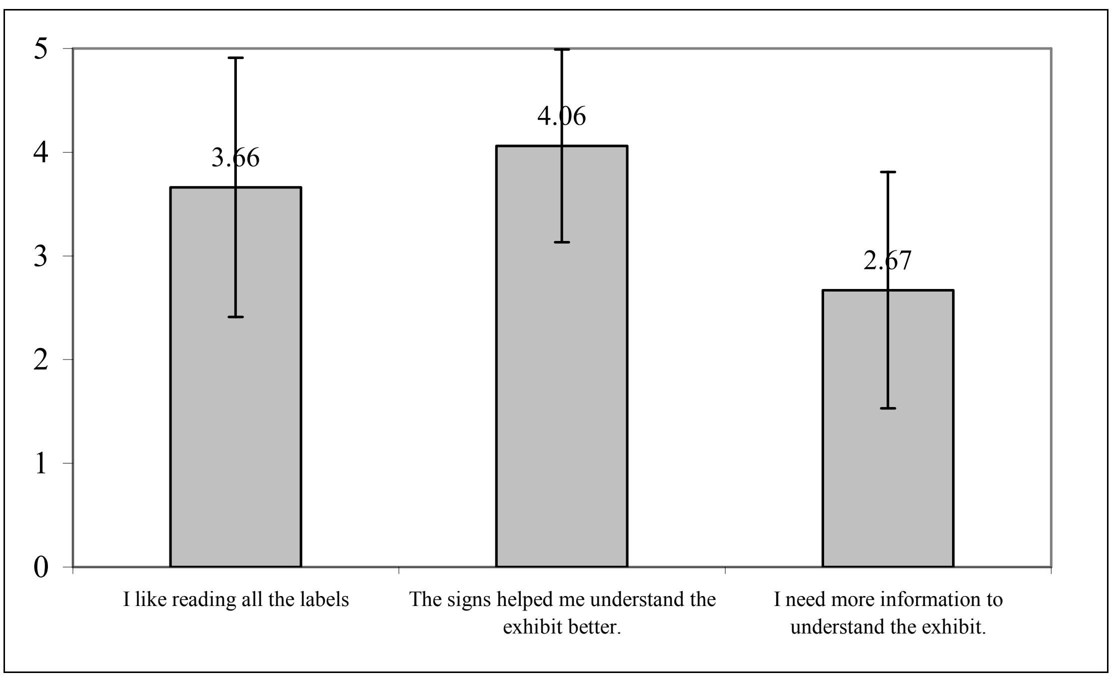


Figure 4.11: Mean Visitor Response for Attitudes Toward the Exhibit Signage

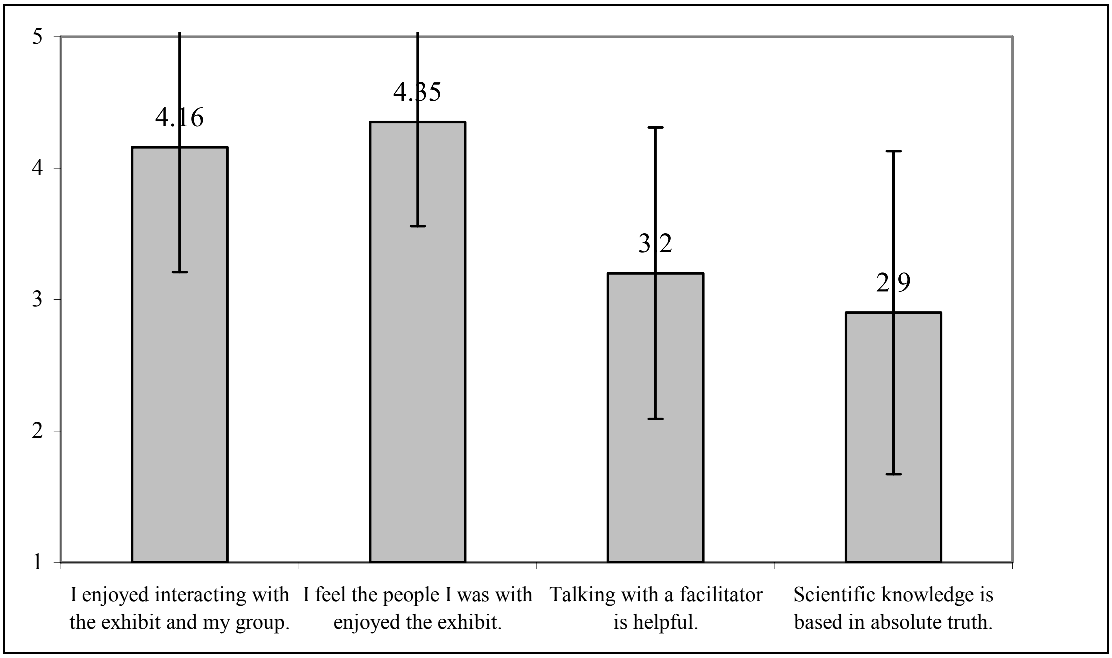


Figure 4.12: Mean Visitor Response for Attitudes Toward Socializing in the Exhibit

Fifty-nine percent responded that they like reading all the labels in the exhibit. Seventy-nine percent felt that the signage helped them understand the exhibit. When asked if more information was needed about the exhibit, visitors responded mixed: 24% felt they needed more information regarding the exhibit, 29% responded neutrally to this statement, while 46.88% responded negatively, indicating that they felt they did not need another source of information about the exhibit. These responses align with visitor responses given in the manipulation section regarding reading signage, where 56.25% responded that they needed an additional source to understand the exhibit, while 43.75% did not.

The social aspects of visiting the science center were also positively received. Eighty percent enjoyed interacting with the exhibit and their group. Eighty-seven percent felt the people they were with enjoyed the exhibit. Thirty-five percent felt that talking with a facilitator was helpful, while 46% responded neutrally. The response rate for neutral feelings may be due to not having met a facilitator with which to interact in the exhibit since they are not stationed within this exhibit. Overall, visitors felt the socialization aspects of the experience were an integral part of their visit. Visitors liked that others in attendance with them at the *Astronaut Training Center* enjoyed their experience, though they were unclear if not having a facilitator present made a difference in their experiences.

Factor Analysis

When designing the initial visitor survey, the attitude questions were divided among three areas of interest: (1) the exhibit, (2) space and astronauts, and (3) learning in general. Questions were developed and assigned to these areas based on their similarity. To establish a relationship between questions in these categories, a factor analysis was performed on the 25 attitude questions following the same methods as used in the interaction analysis.

Three criteria were used to determine the number of factors available in the rotation: the *a priori* hypothesis that the measure was multidimensional (the three areas of interest within the survey; (1) the exhibit, (2) space and astronauts, and (3) learning in general), the scree test, and the interpretability of the factor solution. Analysis of the scree plot for the sharpest decent in eigenvalue before the plateau indicates four dimensions, accounting for 38% of the variance seen within the data and validating the initial hypothesis of having a multidimensional variable. Based on this plot, the four categories were rotated using a VARIMAX rotation procedure. These factors were used to statistically identify questions for which visitors provided similar answers.

The rotated solution, as shown in Table 4.7, yielded three easily interpretable attitude factors:

- Attitude Toward Liking Learning
- Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and the *Astronaut Training Center*
- Attitude Toward Exhibit Theme – Space and Astronauts

The fourth factor identified by the factor analysis was later removed, as how the questions related was difficult to determine and the Cronbach's alpha of reliability was very low.

Questions were deemed to fall under a certain factor if the factor loading values were ±0.4 or greater. Questions with loadings less than 0.4 were not included in the categories. The first factor, Attitude Toward Liking Learning, emphasized visitors' positive responses toward learning, learning science in particular, space travel, and watching educational science television. This factor accounted for 11.09% of the total variance. The Attitude Toward the Atmosphere of the Science Center and Exhibit includes questions that focus on the *Astronaut Training Center* exhibit and visitor interaction with the exhibit and accounted for 10.04% of the total variance. This factor also included the statement, "Scientific knowledge is based in absolute truth." It is unclear why this measure was associated with other measures in this

Table 4.7: Factor Analysis of Visitor Attitude Questions on Initial Visitor Survey

Item Number	Attitude Statements	Factors Ranked by Loading Magnitude			
		1	2	3	4
Attitude Toward Liking Learning					
5b	I like science. [a]	0.76	-0.08	-0.07	0.24
4c	I find space travel interesting.	0.64	0.25	0.10	0.03
5a	I found the exhibit enjoyable.	0.51	0.45	0.11	0.25
5o	I like learning.	0.48	0.22	0.19	-0.08
4d	I like reading all the labels. [a]	0.47	-0.04	0.04	0.17
5f	I like watching educational science television.	0.43	0.33	0.06	0.02
Attitude Toward the Atmosphere of the Science Center and Exhibit - Science City and ATC					
5d	I enjoyed interacting with the exhibit and my group. [a]	0.17	0.68	0.40	0.03
5c	I feel the people I was with enjoyed the exhibit.	0.06	0.57	0.21	0.21
5e	I want to learn more about astronauts.	0.53	0.58	0.12	-0.16
5h	Scientific knowledge is based in absolute truth.	0.1	0.50	-0.12	-0.05
5l	The signs helped me understand the exhibit better.	0.19	0.45	0.44	-0.02
Attitude Toward the Exhibit Theme - Space and Astronauts					
4h	The "Living Quarters" exhibit reflected my expectations of life on a space shuttle.	0.14	0.05	0.66	-0.07
4a	I feel the exhibit added to my understanding of an astronaut's experiences	0.05	0.34	0.66	0.27
4j	Life in a space shuttle is different for life on Earth.	0.12	0.05	0.57	0.07
Attitude Toward "Doing" in the Exhibit*					
5m	I found the exhibit challenging. [a]	0.26	0.25	-0.03	0.65
4i	I feel the Living Quarters exhibit could be more detailed.	0.22	-0.29	0.40	-0.58
4b	I was able to handle or manipulate much in the exhibit. [a]	0.15	0.16	0.03	0.49
5g	I like to read about science in a newspaper. [a]	0.36	-0.06	0.16	0.42

[a] Recoded from the negative to be compared in the positive with the rest of the scale.
* This factor was removed from further analysis based on analysis of Cronbach's alpha.

factor. The third factor identified, Attitude Toward the Exhibit Theme, focused on variance. These statements included visitors' expectations of the exhibit, whether the visitors' attitudes toward the content in the exhibit and accounts for 8.31% of the exhibit added to their understanding of an astronaut's experiences, and whether the visitor felt life in a space shuttle was different from life on Earth. The final factor, Attitude Toward "Doing" in the Exhibit, focused on actions and interactions visitors perform in the exhibit accounts for 8.10% of the variance. This factor is later removed from the analysis.

Inter-factor reliability was determined using Cronbach's alpha (Table 4.8). All factors had moderate reliability, except for the fourth factor, Attitude Toward "Doing", which had low reliability. This indicates a low level of internal consistency within this particular factor. Due to this low level of reliability, it was decided to remove this factor from other comparisons.

Table 4.8: Cronbach's Alpha of Reliability for Attitude Factors

Factor	α	N	M	Variance
Attitude Toward Liking Learning	0.687	6	4.22	0.121
Attitude Toward the Atmosphere of the Science Center and Exhibit	0.682	5	3.85	0.384
Attitude Toward the Exhibit Theme	0.578	3	3.92	0.163
Attitude Toward "Doing" in the Exhibit	0.137	4	3.42	0.021

Correlations with Visitor Demographics

Few demographic variables correlated with the mean scores from the three identified factors. The factor, Liking Learning, correlated significantly at the $p = 0.05$ level with only one demographic, highest level of education, r (93) = 0.212, $p = 0.04$. Exhibit Theme correlated with three variables: highest level of education, r (93) = 0.284, $p = 0.05$, annual household income, r (75) = 00.240, $p = 0.037$, and gender, r (91) = 0.306, $p = 0.003$. The factor, Atmosphere of Science City and the Exhibit, did not correlate significantly with any of the demographic variables. These correlations emphasize the role of education in understanding the importance of visiting informal learning environments and gaining knowledge from these settings.

Inter-Factor Correlations and Correlations with Learning

The mean response to questions within the Attitude Factors was correlated with perceived learning using the Pearson correlation coefficient (Table 4.9). At the $p \leq 0.05$ level, several factors held statistically significant correlations: Liking Learning and Atmosphere of the Science Center. Within these categories, specific statements held statistically significant correlations, such as "I learned something about Mars" (M = 3.14, SD = 0.90), r (73) = 0.352, $p = 0.002$ and "Before my visit, I felt I had a weak knowledge about space exploration" (M = 2.58, SD = 1.04), r (73) = 0.231, $p = 0.048$.

Table 4.9: Correlation between Attitude Factors and Perceived Learning

	Perceived Learning	Liking Learning	Atmosphere of Science Center	Exhibit Theme
Perceived Learning	1.0	0.325**	0.262*	0.223
Liking Learning		1.00	0.431**	0.302**
Atmosphere of Science Center			1.0	0.436**
Exhibit Theme				1.0
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)				

Correlations between Perceived Behavior and Attitude Factors

The mean visitor responses to the behavior and attitude factors were compared using a Pearson correlation coefficient. The results are shown in Table 4.10. The Interaction Factor, Communication, correlated with the Attitude Factors: Liking Learning, r (99) = 0.206, p = 0.04, Atmosphere of the Science Center, r (99) = 0.315, p = 0.001, and Exhibit Theme, r (99) = 0.353, $p \leq 0.01$. This suggests that the exhibit and the science center promote visitor interaction among each other and between the exhibit and the visitors.

The Interaction Factor, Video Game Stations, correlated moderately with Attitude Toward the Atmosphere of the Science Center, r (98) = 0.204, p = 0.043, and Exhibit Theme, r (98) = 0.199, p = 0.048. Interactions with Push-button Stations correlated with Attitude Toward the Atmosphere of the Science Center, r (97) = 0.252, p = 0.012, and the Exhibit Theme, r (97) = 0.204, p = 0.044.

Table 4.10: Correlation between Interaction and Attitude Factors

	Liking Learning	Atmosphere of Science Center	Exhibit Theme
Communication	0.206*	0.315**	0.353**
Video Game Stations	0.133	0.204*	0.199*
Push-button Stations	0.066	0.2552*	0.204*
Talking with Others Outside the Group	-0.035	0.284**	0.143
Eye-hand Coordination	-0.079	0.067	0.154
Astronaut Fitness Test	0.093	0.301**	0.131
Mars Soil Test	0.031	0.111	0.286**

All correlations not shown for clarity.
** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Talking with Others Outside the Group correlated with Attitude Toward the Atmosphere of the Science Center, r (94) = 0.284, p = 0.005. The single exhibit station, Astronaut Fitness Test, correlated with Attitude Toward the Atmosphere of the Science Center as well, r (97) = 0.301, p = 0.003. The Mars Soil Test correlated with Attitude Toward the Exhibit Theme, r (95) = 0.286, p = 0.005.

Summary

Throughout this chapter, some themes began to emerge. Foremost is the importance of social interactions among visitors. Of those visitors who perceived they learned from their experiences with the *Astronaut Training Center* exhibit, social interactions were stronger indicators of perceived learning than physical behaviors, specifically the social interactions talking about the exhibit and reading the signage. Sixty-three percent of respondents indicated that they interacted with the exhibit by talking about the exhibit. Talking about the exhibit also correlated with highest level of education. These visitors seem more willing to explore the area when they find things they do not understand.

The level of manipulating exhibit stations also correlated with talking about the exhibit, while manipulating specific exhibit stations did not, so it is unclear as to what aspects of the different exhibits encourage visitors to talk about their experiences. The *Astronaut Training Center* stations may be challenging enough to manipulate that visitors talk about the interactions more in order to obtain the desired results. Higher levels of interaction were also found to occur mostly with the younger visitors. Manipulating the Mars Rover, for example correlated strongly with college major, where individuals who had non-science majors in college or no college experience rated interacting with this exhibit higher.

Reading the signage was associated with having the greatest effect on visitor behavior within the *Astronaut Training Center* exhibit. Visitors who read the signage typically did what the signs suggested, and 86% found the information helpful. Adults also typically lead children through the exhibit and read the signs to their kids. This produced opportunities for groups to discuss the exhibits and the information pertaining to the stations, increasing social interactions.

Visitors' attitudes toward learning also effected their perception of learning. The attitude factors Liking Learning and Atmosphere of the Science Center correlated strongly with visitors' perception of learning. Many visitors appear to come with these attitudes, but any effect of the exhibit on visitor attitudes in these areas may result in higher perceptions of learning.

No correlations were found between the Interaction factors and visitors' perception of learning. The game-like presentation of the Shuttle Approach Simulator and the Mars Rover may have reduced visitors' perceptions of these exhibits being educational, even in an informal setting. Incorporating signage or some additional aspect to the stations which emphasized the learning aspects of the station may influence these perceptions. This is further explored in the follow-up survey, discussed in the next chapter.

Chapter 5

Follow-Up Visitor Survey

This chapter reports on the second of two surveys of visitors to Science City's *Astronaut Training Center*, examining their perceptions of learning, level of interaction with the exhibit, and their attitudes toward space and science. This survey was administered to collect qualitative and quantitative data about the memories of visitors' interactions during their visit. The follow-up survey was divided into two sections, the results of which are discussed here: visitor interactions with the exhibit (manipulating, interaction, reading, and socializing), and visitor attitudes toward space and science. The results from both sections will be discussed in the following pages and formal comparisons made to the initial survey at the end of this chapter.

Survey Collection

As part of the initial survey, visitors were asked to participate in a follow-up study. Participants who left their contact information were sent either an email or a letter three months after the completion of the initial survey data collection again asking them to participate in the follow-up survey. Responses were collected either through a website or through the returned surveys. Both formats asked visitors the same questions (see Appendix II for the print version). The survey was accompanied by a letter of introduction reminding participants how their contact information was obtained and the purpose of the study (see Appendix IV for these letters). Participants were asked to record the last four digits of their telephone number at the top of the survey, in order to match this survey with initial surveys for comparison. Only four surveys were able to be matched in this manner. Responses were collected between April and May of 2005.

Survey Sample and Demographics

Of the 33 participants who listed contact information on the initial visitor survey, 14 individuals returned completed surveys, a 42% response rate. Demographic information from the initial survey was used to establish the demographics of the follow-up survey sample. Sixty-eight percent of those leaving contact information in order to participate in the follow-up study were female. Ninety-one percent were Caucasian, 3% Asian, and 3% Hispanic and were typically from households with incomes ranging from $50k to $79.9k (Figure 5.1). The majority had advanced college degrees with majors in science and engineering or education (Figure 5.2). It is unknown how this distribution describes the people who actually returned the surveys, due to the low number of surveys able to be matched to the initial survey.

The sample was compared with the visiting population of Union Station (Blue Water Consulting Inc., 2002) in terms of gender and ethnicity using a Chi-squared analysis (Table 5.1). At the $p \leq 0.05$ level, the two samples were determined to be statistically the same for both the gender and ethnicity variables, Chi-squared = 0.629, $p = 0.428$, and Chi-squared = 7.544, $p = 0.056$, respectively. This indicates that the poll of visitors who left information to participate in the follow-up study is reflective of the general visiting audience at Union Station.

Figure 5.1: Gender, Ethnicity and Household Income of Participants in Follow-Up Survey

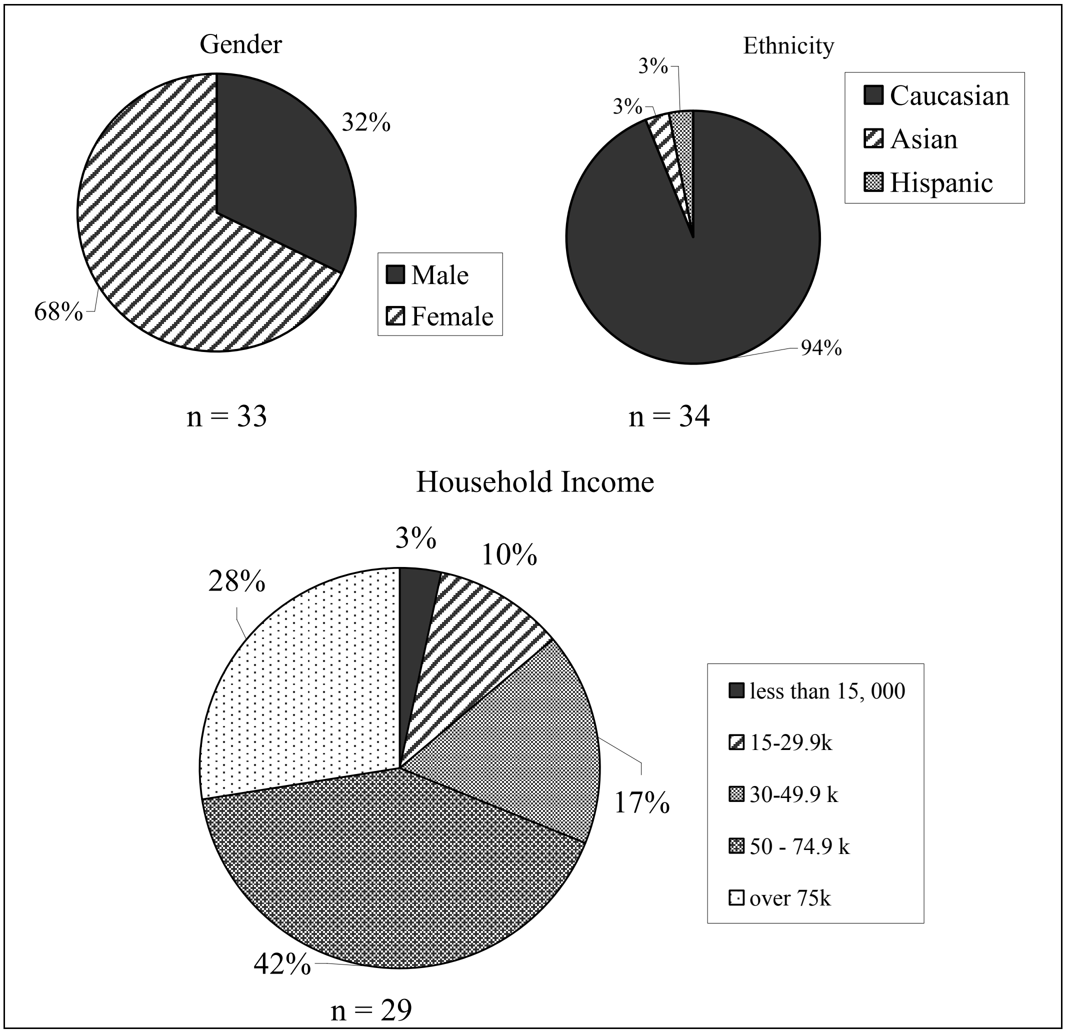


Figure 5.2: Level of Education and College Major of Participants in Follow-Up Survey

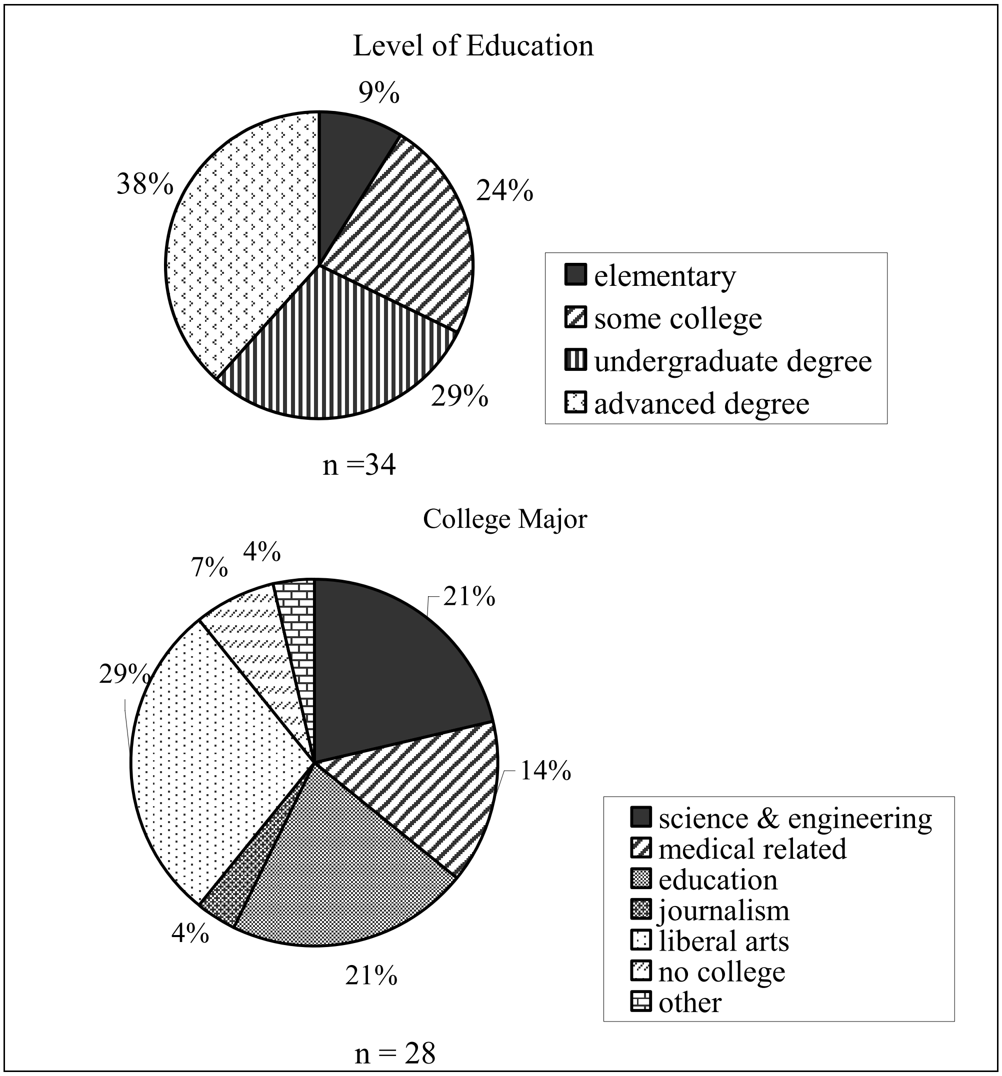


Table 5.1: Percentage Comparison of Union Station Visiting Population and Follow-up Study Sample.

	Union Station[a]	This Study (n = 100)
Sex[b]		
Female	60	23
Male	40	11
No response given		
Race/ethnicity[c]		
Caucasian	86	68
African American	9	17
Asian	2	0
Hispanic	2	0
Other		
No response given		

[a] From *Union Station Kansas City Demographics*, by Blue Water Consulting, Inc., 2002. Kansas City, MO.
[b] Chi-squared = 0.629; $p = 0.428$
[c] Chi-squared = 7.544; $p = 0.056$

Perceived Visitor Behavior and Factor Analysis

Manipulating and Interacting

Visitors to the *Astronaut Training Center* were generally split when recalling how much they manipulated stations within the exhibit a minimum of three months after their initial visit (Table 5.2). One-third of respondents typically rated manipulating specific exhibit stations positively (represented by a combination of response values of four and five), while another third typically rated manipulation negatively (represented by a combination of response values of one and two). For example, 31% of respondents rated having manipulated the Mars Rover, while 31% felt they did not; 38% responded neutrally. Thirty-eight percent of respondents

Table 5.2: Percent Visitor Response to Interaction Questions

	N	Percentage				
		1 Not at all	2	3 Some	4	5 A lot
How much you manipulated the:						
Shuttle Approach Simulator	13	15.38	15.38	30.77	30.77	7.69
Mars Rover	13	7.69	23.08	38.46	7.69	23.08
Mars Soil Test	13	38.46	7.69	23.08	30.77	0.00
"Compatibility Test"	13	38.46	15.38	15.38	23.08	7.69
Robotic Arm	12	16.67	8.33	33.33	8.33	33.33
Astronaut Fitness Test	13	53.85	7.69	15.38	7.69	15.38
"Emergency Repairs"	12	50.00	8.33	25.00	0.00	16.67

indicated that they had manipulated the Shuttle Approach Simulator, while 31% indicated they had not; the remaining 31% responded neutrally to this statement. On average, visitors remembered manipulating the Robotic Arm the most, and had the least recollection of manipulating (participating in) the fitness test.

Large deviations in responses were seen in the follow-up survey, due to the small sample size. This resulted in means being depressed more than expected. A single extreme response had a much larger effect on the mean than would have been found with a larger sample. Had a large sample been obtained, much of the variation among individual responses would have decreased, as each response would have less effect on the overall mean, so the true effect of the exhibit on long-term learning may not be as clear as hoped.

Reading and Socializing

Variance in response to questions regarding reading signage was narrower than those regarding manipulating exhibit stations (Table 5.2 compared to Table 5.3). Sixty-nine percent of visitors responded that they had read the signage. Participants also rated aspects of socialization during their visit highly. When asked how much they talked about the exhibit with the people in their group or family, 61% responded positively (combining responses of four and five). While visitors interacted heavily with those within their group, visitors did not talk with visitors outside their group. Only 8% responded positively to having talked to others outside their group, while the vast majority, 84%, responded negatively. Fifty-four percent of respondents felt they did not talk to Science City facilitators, while 23% responded neutrally. Although interactions within the visiting group were rated highly, guiding someone through the exhibit was rated lower than would be expected, with 50% responding neutrally and 33% rating the item negatively.

Table 5.3: Percent Visitor Response to Reading and Socializing Questions

	N	Percentage				
		1 Not at all	2	3 Some	4	5 A lot
How much you:						
Guided someone through the exhibit.	12	16.67	16.67	50.00	8.33	8.33
Read signage next to the stations.	13	0.00	0.00	30.77	38.46	30.77
Talked about the exhibit:						
With the people in your group or family.	13	7.69	0.00	30.77	23.08	38.46
With other visitors.	13	46.15	38.46	7.69	7.69	0.00
With Science City facilitators	13	46.15	7.69	23.08	15.38	7.69

Visitor Perception of Learning

Seventy-five percent of visitors participating in the follow-up study felt that they had learned something from their visit (combining responses of 4 and 5). To see if their perception of learning changed with time, visitors were again asked to describe what they felt they had learned from the exhibit (Table 5.4). Visitor responses were coded by the level of learning associated with the type of response: identifying, describing, and interpreting and applying (Borun et al., 1996). Fifty percent of visitors described what they learned, stating: "I learned about some of the tools astronauts use," and "it was hard to do what astronaut is required to do." Twenty-one percent responded at the interpreting and applying level. One visitor stated: "How challenging it is to maximize data collection from an environment that we cannot physically travel to." Responses generally emphasized the difficulty of the exhibits and the work of astronauts. This is a shift from the results seen in the initial visitor survey (Table 4.3). More individuals in the follow-up survey described specific pieces of knowledge they gained from their visit. The relative number of visitors who wrote comments at the interpreting and applying level remained constant over time. This is much less than what was seen in Borun, Chambers, Dritsas, and Johnson's (1997) study of visitors to four Philadelphia area science museums. The authors of that study counted the number of behaviors associated with learning, such as asking and answering a question, commenting or explaining the station, and reading signs silently or aloud and found that the average frequency of these indicator behaviors increased with the learning level. In contrast, this study found that the percentage of visitors who left comments that reflected the learning levels described decreased with increasing learning level.

Table 5.4: Percentage of Respondents For Each Learning Level

	N	Percentage		
		Identify	Describe	Interpret and Apply
Describe what you feel you learned from the exhibit.	12	14.3	50	21.4
What do you remember most about your visit to the *Astronaut Training Center*?	12	57.1	14.3	14.3
What would make this exhibit more meaningful to you?	12	21.4	35.7	28.6

Participants were also asked to reflect on their experiences at the *Astronaut Training Center* and state what they remembered the most about their visit. Fifty-seven percent of respondents identified aspects of the exhibit, such as “the landing site,” “the Robotic Arm,” and “the rovers.” Fourteen percent of respondents were able to describe what they remembered, including how “the puzzles they were a great challenge.” One visitor reflected on the difficulty of manipulating the exhibit stations, especially since many were not working during their visit: “Part/most of the exhibits were hard to manipulate I imagine as it is space. However, some were NOT working at all. Which seems to be very common for this exhibit.”

Some visitors also had suggestions on how to make the exhibit more meaningful. Most suggestions centered on visitors wanting to see the exhibit stations working during their next visit. The problem of stations not working within the exhibit plagued this study, as many visitors felt they were unable to comment fairly on some of the questions, due to this issue. This was one of the major reasons cited informally among visitors who chose not to participate in the initial survey. Other suggestions for improvement within the exhibit included having more information about the history of the US space program, links to live TV broadcasts from NASA or the space station, and a simulation of zero-gravity for visitors to experience.

Factor Analysis

Factor analysis was used to identify key behaviors by visitors among the visitor interaction questions. This resulted in the seven factors identified in the initial survey:

- Communicating
- Video Game Stations
- Push-button Stations
- Talking with Others Outside the Group
- Eye-hand Coordination
- Astronaut Fitness Test
- Mars Soil Test

Items on the follow-up survey were matched with questions used on the initial visitor survey within the identified factors (Table 5.5). Questions from the usage portion of the initial questionnaire were omitted in the follow-up survey, so the reliability of the factors for use in the analysis of the follow-up survey was recalculated using Cronbach's alpha (Table 5.6). Reliability for the Communicating Factor was found to be strong; however, reliability was found to be weak for the Video Game Factor and poor for Eye-hand Coordination. Reliability coefficients were not able to be calculated for the remaining factors. Formal comparisons between the initial and follow-up surveys will be discussed at the end of this chapter (see Figure 5.4).

Table 5.5: Mean response to questions in Interaction Factor Analysis

Item	Question	N	M	SD
Communicating				
10	Talked with the people in your group or family.	14	3.57	1.55
2	Read signage next to the station	14	3.71	1.33
6	"Compatibility Test"	14	2.29	1.54
Video Game Station				
3	Shuttle Approach Simulator	14	2.79	1.42
4	Mars Rover	14	2.93	1.49
Push-button Stations				
9	"Emergency Repairs" knobs	13	2.08	1.61
Talking with others outside the group				
11	Talked with other visitors.	14	1.64	1.00
12	Talked with Science City facilitators	14	2.14	1.51
1	Guided someone through the exhibit.	14	2.36	1.45
Eye-hand Coordination				
7	Robotic Arm	13	3.08	1.70
Astronaut Fitness Test				
8	Astronaut Fitness Test	14	2.07	1.64
Mars Soil Test				
5	Mars Soil Test	14	2.29	1.44

Table 5.6: Cronbach's Alpha of Reliability for Interaction Factors

Factor	α	N	M	SD
Communication	0.788	3	3.19	1.24
Video Game Stations	0.440	2	2.86	1.17
Push-button Stations	-	1	2.08	1.61
Talking with Others Outside the Group	0.073	3	2.05	0.79
Eye-hand Coordination	-	1	3.08	1.71
Astronaut Fitness Test	-	1	2.07	1.64
Mars Soil Test	-	1	2.29	1.44

Correlation with Visitor Demographics

Relationships between demographic variables and visitors' memories of their interactions within the exhibit were explored using the data available for the individuals matched to their initial survey. This resulted in many of the responses having sample sizes containing three or four individuals and resulted in no significant correlations. This result was dramatically affected by the small sample size and the inability to generalize the findings to other cases.

Inter-factor Correlations and Correlations with Learning

In contrast to the initial visitor survey, the follow-up survey asked visitors to use a Likert scale to rate how much they agreed with the statement, "I learned something from this exhibit." This was done to obtain better correlations with the other Likert scaled questions in the survey. Results are shown in Table 5.7. No statistically significant correlations were found between the Interaction Factors and perceived learning. All statistically significant inter-factor correlations found in the initial visitor survey were also significant in the follow-up survey (compare Table 5.7 with Table 4.6). Correlations that were not statistically significant in the initial visitor survey were significant in the follow-up survey. This result is affected by the small sample size that plagues the follow-up survey.

Table 5.7: Correlation Between Visitor Perceived Learning and Interaction Factors

		Factor						
		1	2	3	4	5	6	7
Do you feel you learned anything from the exhibit?		0.188	0.074	-0.16	0.242	0.081	-0.149	-0.05
Factor	1 Communication	1	0.854**	0.683*	0.825**	0.690**	0.725**	0.788**
	2 Video Game Stations		1	0.713**	0.727**	0.806**	0.589*	0.622*
	3 Push-button			1	0.817**	0.850**	0.740**	0.659*
	4 Talking with Others Outside the Group				1	0.746**	0.687**	0.616*
	5 Eye-hand coordination					1	0.485	0.620*
	6 Astronaut Fitness Test						1	0.48
	7 Mars Soil Test							1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Visitor Attitude and Factor Analysis

A portion of the attitude questions from the initial survey were used in the follow-up survey to gauge the change in visitor perceptions of their experiences and attitudes between their visit and taking the follow-up survey. As individual stations, the Shuttle Approach Simulator and Mars Rover did not correlate significantly with visitors' perceptions of learning in the initial survey. It was thought that the arcade game-like presentation was impeding visitors' perceptions of learning. This idea was explored by asking visitors about their attitudes toward video games as learning tools. As the factors developed in Chapter 4 had not been identified prior to the implementation of the follow-up study, few questions from each attitude factor were used. It was felt that in order to encourage participants to complete and return the survey, the length had to be dramatically shortened. Much of this came at the expense of the attitude questions.

Attitudes toward Space Exploration and the Exhibit

Visitor attitudes toward space exploration and the exhibit were generally lower than in the initial survey. Seventy-five percent of visitors found the exhibit enjoyable after their visit, combining responses 4 and 5 (Table 5.8). Forty-one percent found the exhibit challenging. Sixty-one percent found enough to do in the exhibit. When asked about their prior knowledge of space exploration, 23% felt they had a weak knowledge about space exploration, while 54% responded negatively, implying that visitors felt they did had knowledge of space exploration.

Visitors also had positive feelings about the exhibit signage and talking about the exhibit. Eighty-six percent of visitors felt the signage was helpful. Ninety-one percent felt the people they were with enjoyed the exhibit. Seventy-one percent enjoyed interacting with their group and the exhibit. Forty-six percent felt that talking with a facilitator was helpful. Even after a lapse of 3 months to a year, the effect of socialization on visitors' attitudes was still positive and substantial. Seventy-five percent of visitors still reported having learned something from their experiences.

Responses to the use of computer technology within the exhibit were generally positive as well. Seventy-nine percent of visitors felt that computer technology is a valuable learning tool. Fifty percent of visitors felt that video games

Table 5.8: Percent Visitor Response to Attitude Questions

	N	Percentage				
		1 Not at all	2	3 Some	4	5 A lot
13. I found the exhibit enjoyable.	14	7.14	0.00	7.14	21.43	64.29
14. I feel the people I was with enjoyed the exhibit.	14	7.14	0.00	21.43	28.57	42.86
15. I enjoyed interacting with the exhibit and my group.	14	7.14	0.00	21.43	35.71	35.71
16. I want to learn more about astronauts.	13	7.69	46.15	38.46	7.69	0.00
17. Before my visit, I feel I had a weak knowledge about space exploration.	13	30.77	23.08	23.08	15.38	7.69
18. I found enough to do in this exhibit.	13	7.69	7.69	23.08	30.77	30.77
19. Talking with a facilitator is helpful.	13	7.69	7.69	38.46	23.08	23.08
20. The signs helped me understand the exhibit better.	14	7.14	7.14	0.00	50.00	35.71
21. Computer technology is a valuable learning tool.	14	14.29	0.00	7.14	14.29	64.29
22. I find the exhibit challenging.	14	21.43	14.29	21.43	14.29	28.57
23. Computer simulations help me feel more like an astronaut.	14	14.29	14.29	35.71	21.43	14.29
24. I feel that I have a better understanding of what an astronaut does.	14	7.14	21.43	14.29	35.71	21.43
25. Video games are teaching tools.	14	7.14	0.00	42.86	28.57	21.43
26. I learned something from this exhibit.	12	8.33	8.33	8.33	50.00	25.00

are learning tools, and 36% felt that the computer simulations helped them feel more like an astronaut. Visitors feel that the use of this technology has its place as a learning tool, but how the technology is presented within the exhibit has an effect on whether it is perceived as a valuable learning tool or as a video game.

Factor Analysis

The initial visitor survey identified three interpretable attitude factors:

- Liking Learning
- Atmosphere of the Science Center and Exhibit – Science City and the *Astronaut Training Center*
- Exhibit Theme – Space and Astronauts.

Items in the follow-up survey were matched to those in the initial survey attitude factors. Mean responses to the follow-up questions from the attitude portion are presented in Table 5.9. As the follow-up survey was implemented prior to the factor analysis on the data for the initial visitor survey, many of the factors were represented by only one question.

As there were questions added to this survey, the factor analysis was preformed again using the same methods as described in Chapter 4. This was to ensure the identified factors were stable across the two surveys. While the scree plot identified between four and seven factors, rotation of the eigenvalues was unable to produce valid factors due to the small sample size. The added questions regarding visitors' perceptions of video games as learning were then treated as a factor themselves. Cronbach's alpha for this factor was 0.715, indicating that the items are highly reliable at predicting visitor's responses to this type of question. Means and reliabilities for all attitude factors are reported in Table 5.10.

Table 5.9: Mean Response to Factor Questions

Item		N	M	SD
Factor 1: Attitude Toward Liking Learning				
13	I found the exhibit enjoyable.	14	4.31	0.53
Factor 2: Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and ATC				
15	I enjoyed interacting with the exhibit and my group.	14	4.93	1.14
14	I feel the people I was with enjoyed the exhibit.	14	4.00	1.18
16	I want to learn more about astronauts.	13	3.38	0.96
20	The signs helped me understand the exhibit better.	14	4.00	1.18
Factor 4: Attitude Toward Video Games as Learning Tools				
21	Computer technology is a valuable learning tool.	14	4.14	1.46
23	Computer simulations help me feel more like an astronaut.	14	3.07	1.27
25	Video games are teaching tools.	14	3.57	1.09

Table 5.10: Cronbach's Alpha of Reliability for Follow-up Survey Attitude Factors

Factor	N	M	SD	α
Factor 1: Attitude Toward Liking Learning	1	4.36	1.56	--
Factor 2: Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and ATC	4	3.83	0.30	0.895
Factor 4: Attitude Toward Video Games as Learning Tools	3	3.60	0.54	0.715

Note: No questions from Factor 3 were included in the follow-up survey.

Inter-Factor Correlations and Correlations with Learning

The mean response to questions identified as part of the three Attitude Factors in the initial survey and the new video game factor were correlated with perception of learning using the Pearson correlation coefficient. No statistically significant correlation was found between these three variables (Table 5.11). No statistically significant correlations were found between the attitude factors and demographic variables such as level of education, college major, annual household income, ethnicity, and gender and are therefore not reported in this document.

Significant correlations were found between the Attitude Factor Liking Learning and the Atmosphere of the Science Center and the Exhibit, r (13) = 0.810, p = 0, and Attitude Toward Video Games as a Learning Tool, r (13) = 0.617, p = 0.001. As visitors have higher attitudes toward enjoying learning, their attitude toward the science center and associating video games with learning in the exhibit also increases. This shows the important role intrinsic motivation to learn plays in informal learning. Visitors who like to learn seek out educational sites and generally felt positively to the educational opportunities available at Science City.

The factor, Attitude Toward Video Games as Learning Tools correlated with the Attitude Toward Atmosphere of the Science Center, r(13) = 0.829, $p < 0.01$. This suggests that the use of the video game technology is seen as appropriate for the environment in Science City due to the emphasis placed on interactions with content. Due to size and cost restraints, much of the content related to space and astronauts is easier to portray through video technology than by blasting students into space.

Table 5.11: Correlations between Attitude Factors in Follow-up Study and Learning

	I learned something from this exhibit.	Factor		
		1	2	5
I learned something from this exhibit.	1	0.459	0.406	0.514
Factor 1: Attitude Toward Liking Learning		1	0.810**	0.764**
Factor 2: Attitude Toward the Atmosphere of the Science Center and Exhibit			1	0.829**
Factor 5: Attitude Toward Video Games as Learning Tools				1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Note: No questions from Factor 3 were included in the follow-up survey.

Correlations between Interaction and Attitude Factors

The means for Interaction and Attitude Factors in the follow-up survey were correlated using the Pearson correlation coefficient. The results are shown in Table 5.12. The Interaction Factor, Communication, correlated with the Attitude Factors Liking Learning, r (13) = 0.776, p = 0.001 and Atmosphere of the Science Center, r (13) = 0.690, p = 0.006. The Interaction Factor labeled Video Game Stations correlated with all the Attitude Factors: Liking Learning, r (13) = 0.785, p = 0.001, Atmosphere of the Science Center, r (13) = 0.686, p = 0.007, and Video Technology, r (13) = 0.571, p = 0.033. Talking with Others correlated with all of the Attitude Factors: Liking Learning, r (13) = 0.738, p = 0.003, Atmosphere of the Science Center, r (13) = 0.604, p = 0.0.022, and Video Technology, r (13) = 0.647, p = 0.012.

Eye-hand coordination correlated with Liking Learning, *r* (12) = 0.690, *p* = 0.009. The Mars Soil Test correlated with Attitude Toward Liking Learning, *r* (13) = 0.585, *p* = 0.028.

Table 5.12: Correlations between Interaction and Attitude Factors

		Attitude Factors		
		Liking Learning	Atmosphere of Science Center	Video Technology
Interaction Factors	Communication	0.776**	0.690**	0.497
	Video Game Stations	0.785**	0.686**	0.571*
	Push-button Stations	0.549	0.364	0.543
	Talking with Others Outside the Group	0.738**	0.604*	0.647*
	Eye-hand Coordination	0.690**	0.375	0.524
	Astronaut Fitness Test	0.475	0.352	0.34
	Mars Soil Test	0.585*	0.345	0.12

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Note: Other correlations omitted for clarity.

<u>Comparison with Initial Survey</u>

The initial and follow-up surveys were compared to determine if visitors' perceptions of learning increased with time. Falk and Dierking's Conceptual Model of Learning suggests that learning in informal environments takes place not only at the initial point of visit, but over time, as individuals digest information which they came in contact with and link it with other experiences and prior knowledge (2000). The time lapse is reflected in this study by the lapse of time between the administration of the initial and follow-up survey.

The means for the Interaction and Attitude Factors were compared visually. For the interaction categories, Communication, Video Game Stations, Talking with Others, and Eye-hand Coordination, an increase in the mean was seen from the initial to the follow-up survey (Figure 5.3). The remaining Interaction Factors saw a decrease in the means between the two surveys. The Attitude Factors also saw fluctuations between the initial and final survey (Figure 5.4). The mean for the Liking Learning factor increased, while the mean for the Atmosphere of the Science Center remained the same. Questions from the Exhibit Theme factor were not included in the follow-up study.

The number of surveys able to be matched between the initial and follow-up survey resulted in five pairs of individual's data. A one-way repeated measure analysis of variance (ANOVA) was used to determine if the means of the two measures, the initial and follow-up survey, differed significantly (Green & Salkind, 2003). This analysis examines how multiple observations on a scale change. Individuals can also be matched using one or more variables, such as gender, age, socio-economic status, to provide multiple measurements. In this case, the factor was defined as the being either the initial or follow-up survey. Dependent variables were defined as the mean response for the seven interaction factors and the three included attitude factors. As there are only two levels to this design, the standard univariate F test was calculated. SPSS calculates results for three tests: the standard univariate F test, alternative univariate tests, and multivariate tests. All tests evaluate the hypothesis that the population means are equal for all levels of the factor.

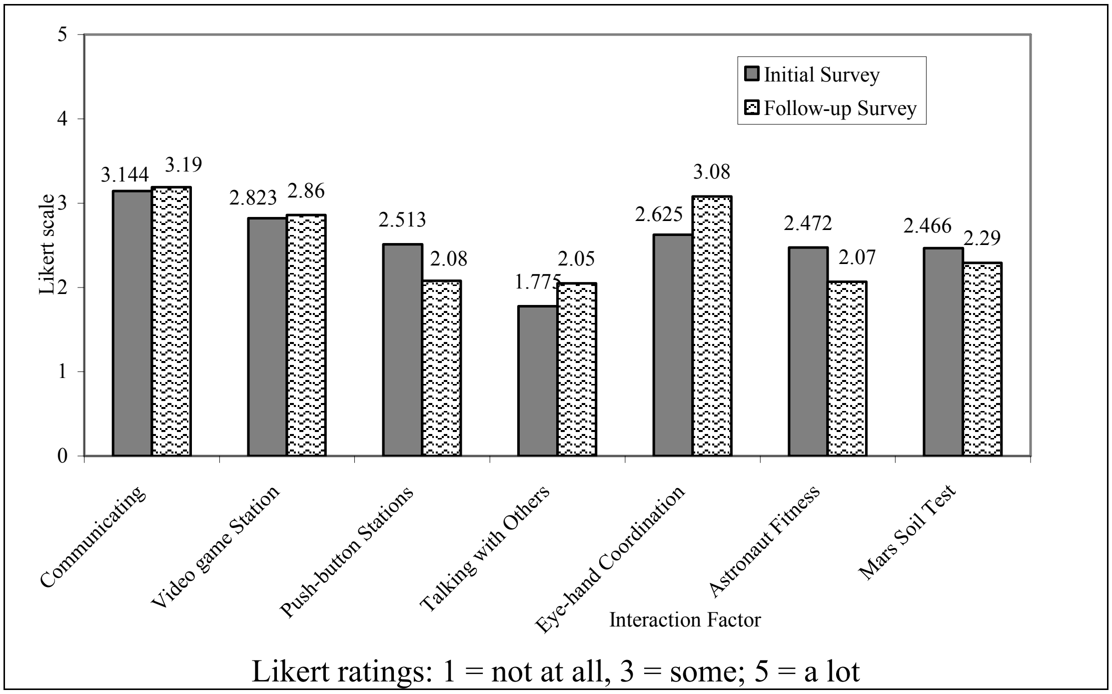


Figure 5.3: Mean Scores for Initial and Follow-up Surveys' Interaction Factors

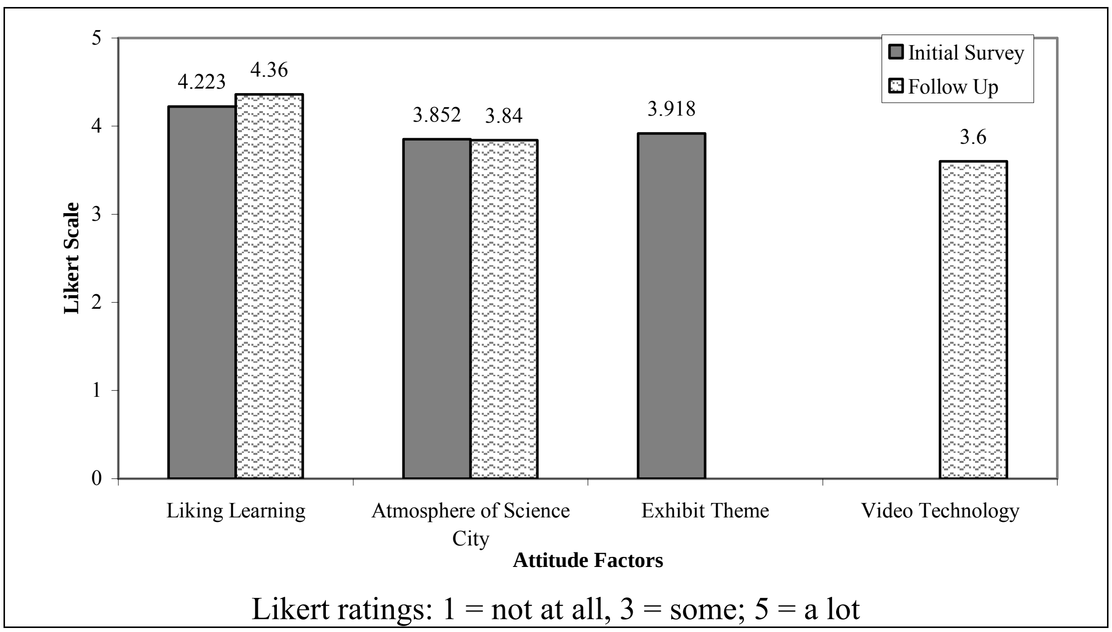


Figure 5.4: Mean scores for Initial and Follow-up Surveys' Attitude Factors

The standard univariate *F* test involves three assumptions: (1) the dependent variable is normally distributed in the population for each level of the factor, (2) the population variance of difference scores is the same regardless of which two levels within a factor are used, and (3) the cases represent random samples within the population and there is no dependency in the scores between participants. ANOVA's will produce reasonably accurate results when Assumption 1 is violated for sample sizes of 30 individuals or larger. For this analysis, only five pairs were identified as being matched based on linking the responses on the follow-up survey to initial surveys. The small sample size violates the reasonability of *F* test results by violating this assumption. Assumption 2, also called the sphericity and the homogeneity-of-variance-of-differences assumption, is only meaningful when there are more than two levels to the factor. This assumption is violated in this case, as there are only the two levels, responses on the initial and follow-up surveys. As such, one of the alternate methods is evaluated. The alternative univariate test corrects the degrees of freedom to account for violation of the second assumption, while the multivariate approach does not require the sphericity assumption.

As this study violates both the first and second assumption, the multivariate test was analyzed. Assumptions must also be made to use the multivariate test. First, the difference scores are assumed to be multivariately normally distributed in the population. To the extent that the sample size is small, the *p* values may not be reliable. The power may also be reduced as a result. The second assumption states that individual cases represent a random sample from the population, and the difference score for any subject are independent from the scores of others. This assumption follows the third assumption from the standard univariate *F* test. The means and standard deviations for the initial and follow-up survey repeated measures are shown in Table 5.13. The results for the ANOVA indicate no statistically significant time effect for the matched individuals. The effect size, reported as the partial eta squared, was small for all of the effects analyzed, indicating a low relationship between the repeated-measures factor and the dependent variables.

To see if the violation of the sample size assumption had an effect on the statistical significance of the results, the two samples were treated as two independent samples and an independent samples *t*-test was conducted (Table 5.14). This allows for all of the individuals participating in the follow-up survey to be included in the analysis as well as all of the respondents in the initial survey. The independent samples *t*-test makes three major assumptions about the data: 1) the test variable is normally distributed in both populations, 2) the variances for the test populations are equal, and 3) the cases represent a random sample from the population and the scores on the test variable are independent of each other (Green & Salkind, 2003). The results of Levene's test can be used to evaluate the extent in which the second assumption is violated. A significant Levene's test would mean that the equality of variance assumption was violated and therefore cannot be assumed, resulting in the need to report the *t*-test values for the non-equality of variance assumption.

Table 5.13: One-way Repeated Measures ANOVA – Multivariate *F* test for Interaction and Attitude Factors

Factor	N	Mean	SD	Wilks' lambda	F (m df, n df)	p	η^2
Interaction Factor							
Communicating							
Initial Follow-up	5 5	2.70 2.33	0.69 1.43	0.892	0.484 (1,4)	0.525	0.108
Video Game Stations							
Initial Follow-up	5 5	2.15 2.10	1.38 1.29	0.997	0.012 (1,4)	0.919	0.003
Push-button stations							
Initial Follow-up	4 4	1.37 1.25	0.75 1.26	0.991	0.026 (1,3)	0.882	0.009
Talking with Others							
Initial Follow-up	4 4	2.67 1.75	0.61 1.20	0.712	1.214 (1,3)	0.351	0.288
Eye-hand Coordination							
Initial Follow-up	4 4	1.50 2.25	1.00 2.22	0.750	1.00 (1,3)	0.391	0.250
Astronaut Fitness Test							
Initial Follow-up	5 5	1.20 1.80	0.45 1.64	0.880	0.545 (1,4)	0.501	0.120
Mars Soil Test							
Initial Follow-up	5 5	2.00 1.60	1.17 1.52	0.680	1.882 (1,4)	0.242	0.320
Attitude Factors							
Liking Learning							
Initial Follow-up	5 5	4.17 1.60	1.17 1.52	0.680	1.88 (1,4)	0.242	0.320
Atmosphere of Science City							
Initial Follow-up	5 5	3.96 3.30	0.38 1.48	0.772	1.182 (1,4)	0.338	0.228

F (m df, n df) indicates the F test's degrees of freedom for m = hypothesis and n = error.

η^2 is a measure of effect size, for the multivariate test, it is reported as the partial eta-squared.

Levene's test was non-significant across all factors, except for the Attitude Factor Liking Learning (Figure 5.14). For this factor, the assumption of equal variances for the test variable (Liking Learning) was violated, so the *t*-test using the non-equal variance was reported. While Figure 5.3 and 5.4 indicate that the factor's mean changed between the initial and follow-up survey, analysis of the independent samples *t*-test indicates that the difference between the means were not statistically significant.

Table 5.14: Results of Independent Samples *t*-Test using Initial and Follow-up Surveys' Interaction and Attitude Factors

	Levene's Test for Equality	Sig.	Equal variance assumed	*t*	df	Sig.
Interaction Factor						
Communicating	1.19	0.278	Yes	-0.269	112	0.788
Video Game Stations	0.06	0.799	Yes	-0.445	111	0.657
Push-button stations	1.03	0.312	Yes	1.175	109	0.242
Talking with Others	2.59	0.111	Yes	1.340	107	0.183
Eye-hand coordination	0.04	0.836	Yes	-1.047	105	0.297
Astronaut fitness	1.45	0.231	Yes	1.212	110	0.228
Mars Soil Test	1.53	0.221	Yes	0.332	108	0.740
Attitude Factor						
Liking Learning	7.84	0.006	No	-0.530	14.0	0.605
Atmosphere of Science City	0.25	0.621	Yes	0.084	112	0.933

Describing Learning

Individuals' descriptions of what they felt they learned from the *Astronaut Training Center* exhibit were compared using a one-way, repeated measures ANOVA between the initial and follow-up surveys. The means and standard deviations are shown in Table 5.15. The results for the ANOVA indicate a non-significant time effect, Wilks' $\Lambda = 0.667$, $F(1, 2) = 1.00$, $p > 0.05$.

Table 5.15: One-way Repeated Measures ANOVA – Multivariate *F* test Comparing Visitor's Descriptions of Learning

Factor	N	Mean	SD	Wilks' lambda	F (m df, n df)	p	η^2
Please describe what you feel you learned from this exhibit.							
Initial Follow-up	3 3	2.00 2.33	1.00 1.15	0.667	1.00 (1,2)	0.423	0.333

__**Summary**__

A sample of self-selected visitors who participated in the initial visitor survey were sent a follow-up survey in order to determine if time had an effect on their attitudes and perceptions of learning. These individuals were generally women of Caucasian decent. Seventy-five percent of visitors participating in the follow-up study felt that they had learned something from their visit, down from 86% in the initial visitor survey.

Mean response to the Interaction Factors: Communication, Video Game Stations, Talking with Others, and Eye-hand Coordination, appeared to increase slightly with time, while the factors Push-button Stations, Astronaut Fitness Test, and

Mars Soil Test decreased. The changes in the mean for all of the Interaction Factors were not statistically significant using both one-way, repeated-measures ANOVA with a sample size of five and an independent samples *t*-test to account for the difference in sample size between the initial and follow-up survey. No statistically significant correlations were seen in the follow-up survey between the Interaction Factors and Perception of Learning. Visitors' level of learning was compared over time. The mean appeared to have a slight increase, but this result was not statistically significantly different. No statistically significant differences were seen between the initial and follow-up survey between the Attitude Factors.

The small sample size for the follow-up survey had a large effect on the statistical results reported in this chapter. It is thought that if more matched surveys could have been collected and compared that the results would have more power to make a statistical decision. As the power is low in this study, none of the comparisons were statistically significant. In the next chapter, the results of the Staff survey will be discussed and compared with the initial and follow-up surveys.

Chapter 6

Staff Survey

This chapter reports on the survey of facilitators at Science City and their perceptions of what visitors do within the *Astronaut Training Center*. Facilitators were asked questions regarding what they felt the visitors did within the exhibit and their personal attitudes toward science, learning, and the nature of the exhibit. The study collected both qualitative and quantitative data about the facilitators' perceptions of visitors. The survey was divided into two sections like the visitor surveys: interaction and attitude. Demographic data such as the age and gender of these individuals was not collected as part of the survey.

Survey Collection

After the completion of the initial survey and behavioral analysis data collection, facilitators at Science City were asked to complete a two page questionnaire. A verbal description was given to the facilitators regarding the nature of the research project and importance of obtaining their approval prior to participating in the study. Consent to participate in the research study was given based on completion and return of the survey. No demographic information was collected from individuals, but it is noted that the group was approximately half male and half female. All were Caucasian and were generally under 30 years old. Fifteen surveys were handed out, eight were returned completed. Data collection occurred during a morning meeting, with facilitators having the option to return the survey at a later date by mail. No surveys were returned in this manner therefore, all surveys in this analysis were collected at one point in time.

<u>Staff Perception of Visitor Behavior</u>

Interacting and Reading

Staff members were asked to rate how much they felt visitors interacted with the exhibit stations in the *Astronaut Training Center*. Percent responses for each station are shown in Table 6.1. Staff members rated the Shuttle Approach Simulator as being the most frequently interacted station examined in the exhibit, the Mars Rover the second most. Staff members also felt that visitors talked about the exhibit more with members of their group or family than they did other visitors. Staff members were generally mixed on the relative amount of visitors who guided someone through the exhibit.

Table 6.1: Percent Response to Science City Staff Member's Perceptions of Visitor Interactions (N = 8 for all questions)

Question		Percentage				
		Not at all		Some		A lot
1. Do you feel visitors:						
a. manipulate the						
i	Shuttle Approach Simulator			12.5	37.5	50
ii	Mars Rover		25	12.5	25	37.5
iii	Mars Soil Test		25	62.5	12.5	
iv	"Compatibility Test" to center the Earth on the screen		37.5	37.5	25	
v	Robotic Arm		12.5	50	12.5	25
vi	Astronaut Fitness Test		12.5	50	12.5	25
vii	"Emergency Repairs" knobs		37.5	62.5		
b. talked about the exhibit:						
i	With the people in their group or family.	12.5	12.5	50	25	
ii	With other visitors.	25	50	25		
c	Guided someone through the exhibit.	25	37.5	37.5		

Generally, staff members felt visitors did not read the signage next to the stations (Table 6.2). This is in stark contrast to what visitors' reported, where 88% of visitors indicated that they read the signage next to the stations (see Table 4.2). Of those who felt that visitors did read the signage, staff members were split as to whether that resulted in visitors performing the tasks indicated in the signs. All respondents felt the signage was helpful when playing with the exhibit and that the signage answered questions about the exhibit.

Table 6.2: Percent Response of Staff Members Regarding Visitors Reading the Signage

Question	N	Percentage	
		No	Yes
Do visitors read the signage next to the station?	8	50	37.3
If you answered yes:			
Do they do what the signs say?	7	50	50
Do you think the signs are helpful when playing with the exhibit?	4	0	100
Did the signs answer your questions about this exhibit?	4	0	100

Staff Perceptions of the Nature of Science

As an easily accessible communicator of science to the public, science center staff play an important role in helping the public understand the nature of science (Rose, 2003). Prior to being able to communicate science to the public, the communicator has to have an understanding of the nature of science. To explore this issue, an open-ended question regarding the staff members' understanding of the nature of science was included in the staff survey. All eight participants wrote responses describing their understanding of the nature of science. Three of the eight respondents openly described the nature of science as an on-going process, one stating "that science is a process of gain[*ing*] new knowledge about the world. It doesn't necessarily follow a prescribed path such as the so-called 'scientific method'." Two people described science in terms of discovery and exploration, stating "the nature of science is discovering how natural processes work ([*across*] all science disciplines) and creating new methods and technologies for human use." The remaining individuals indicated that they had no understanding of the nature of science, a startling discovery to find in an environment where the facilitators are supposed to be helping visitors develop a deeper understanding of not only the content presented but the nature of science as well.

Facilitators were also asked what they thought was the main purpose of the *Astronaut Training Center*. Some responses were identified as belonging to more than one category. Four individuals responded that the exhibit was meant to create and/or solidify positive attitudes toward space science. One individual wrote that the purpose of the exhibit was to "get people excited about Space Science and allow them to explore concepts related to it. I do not think the purpose is to impart scientific knowledge/content." Four people responded that visitors having experiences related to space was important, one stating, "it's as close as some will get to being in space." One individual responded that gaining content knowledge was the main purpose of the exhibit.

When asked what scientific knowledge facilitators felt that visitors should learn from the exhibit, five responded that content knowledge was important. One stated visitors should learn "fact[*s*] about space travel, work, and living. Facts about other planets and celestial bodie [*in original*] in our solar system and the universe." Three individuals responded that coming away with positive attitudes toward space and science were important outcomes. Two more responded that the process of doing science was important, that "astronauts and space scientists use many different tools. Living in space requires specialized equipment due to the lack of gravity and air in space." Again, some individual's responses fell under more than one category.

Factor Analysis

The factor analysis conducted in the initial visitor survey identified seven factors associated with the interactions between visitors and the exhibit space:

- Communicating
- Video Game Stations
- Push-button Stations
- Talking with Others Outside the Group
- Eye-hand Coordination
- Astronaut Fitness Test
- Mars Soil Test

Items on the staff survey were matched with questions from the initial visitor survey within these identified factors (Table 6.3). With the shortening of the staff survey from the length of the initial survey, the number of questions used in the factor analysis was limited. The reliability for factors containing multiple questions was recalculated using Cronbach's alpha to add validity to the survey (Table 6.4).

Table 6.3: Mean Response to Questions in Interaction Factor Analysis

Item	Question	N	M	SD
Communicating				
1bi	Talked about the exhibit with the people in their group or family.	8	2.88	0.99
1bii	Talked about the exhibit with other people.	8	2.00	0.76
2	Do visitors read the signage next to the stations? (yes/no)	7	0.43	0.54
1aiv	"Compatibility Test" to center the Earth on the screen.	8	2.88	0.83
Video Game Station				
1ai	Shuttle Approach Simulator	8	4.38	0.74
1aii	Mars Rover	8	3.75	1.28
Push-button Stations				
1avii	"Emergency Repairs" knobs	8	2.63	0.52
Talking with Others Outside the Group				
1c	Guided someone through the exhibit.	8	2.13	0.83
Eye-hand Coordination				
1av	Robotic Arm	8	3.50	1.07
Astronaut Fitness Test				
1avi	Astronaut Fitness Test	8	3.50	1.07
Mars Soil Test				
1aiii	Mars Soil Test	8	2.88	0.64

Table 6.4: Cronbach's Alpha of Reliability for Interaction Factors

Factor	N	M	SD	α
Communication	4	2.00	1.15	-0.218
Video Game Stations	2	4.06	0.44	0.527
Push-button Stations	8	2.63	0.52	-
Talking with Others Outside the Group	8	2.13	0.83	-
Eye-hand Coordination	8	3.50	1.07	-
Astronaut Fitness Test	8	3.50	1.07	-
Mars Soil Test	8	2.88	0.64	-

The reliability for the Video Game Stations factor was found to be moderately positive, while the Communication factor was found to be weakly negative. The negative result is indicative of the negative responses facilitators had toward how they thought the visitors interacted with each other. Formal comparisons among the initial, follow-up and staff surveys will be conducted at the end of this chapter.

Inter-Factor Correlations and Correlations with Staff Perception of Visitor Learning

The mean staff responses to the Interaction Factors were correlated to facilitators' perceptions of visitor learning using the Pearson correlation coefficient. No statistically significant correlations at the $p \leq 0.05$ level were present. Inter-factor correlations were also examined and no statistically significant correlations were found.

Table 6.5: Correlations between Staff Perception of Visitor Learning and Interaction Factors

		Factor						
		1	2	3	4	5	6	7
I feel that learning occurs at this exhibit.		-0.361	0.402	-0.447	-0.647	0.289	0.289	-0.120
Factor	1 Communicate	1	0.016	0.485	0.568	0.417	0.209	0.652
	2 Video games		1	-0.260	-0.310	0.348	0.658	0.403
	3 Push-button			1	0.455	0.645	-0.129	0.269
	4 Talking w/ others				1	0.080	0.240	0.568
	5 Eye/hand coordination					1	0.375	0.521
	6 Astro. Fitness Test						1	0.521
	7 Mars Soil Test							1

Staff Attitudes Toward Space and Science

The facilitators at Science City were surveyed to determine what attitudes they held regarding the manner in which the content was presented within the exhibit. Questions were designed to identify what facilitators feel visitors are doing in the exhibit, outside of the specific exhibit stations which visitors interacted. It also is meant to identify attitudes held by facilitators toward their role within the exhibit and how the exhibit itself attempts to compensate for no facilitator presence. The results are shown in Table 6.6. Seventy-five percent felt that learning occurred in the exhibit. Sixty-two percent of the respondents felt that the exhibit added to a visitor's understanding of an astronaut's experiences.

Facilitators were split over whether visitors learned something about Mars from the exhibit, as 62.5% responded favorably while 37.5% responded unfavorably. Seventy-five percent of facilitators felt the signs helped visitors understand the exhibit better but were unsure whether visitors needed additional information in order to understand the exhibit. Eighty-seven percent felt that talking with a facilitator was helpful.

The majority of facilitators (62.5%) were unsure whether there was enough for visitors to do within the Astronaut Training Center. Fifty percent felt that visitors were able to handle or manipulate much within the exhibit. Seventy-five percent of facilitators felt the Living Quarters room within the exhibit could have been more detailed.

Table 6.6: Percent Response of Staff Members' Attitudes Toward the *Astronaut Training Center* Exhibit and Science (N = 8)

Questions		Percentage				
		Mostly Disagree 1	2	Neutral 3	4	Mostly agree 5
3. Please indicate your level of agreement.						
a.	I feel the exhibit adds to visitors' understanding of an astronaut's experiences.			37.5	25	37.5
b.	Visitors are able to handle or manipulate much in the exhibit.		12.5	37.5	50	
c.	Reading the labels is useful to understanding the exhibit.			25	50	25
d.	Visitors can learn something about Mars from the exhibit.	12.5	25		50	12.5
e.	I feel the Living Quarters exhibit could be more detailed.			25	37.5	37.5
4. Based on your experience, please indicate your level of agreement.						
a.	There is enough to do in this exhibit.	12.5	12.5	62.5		12.5
b.	Talking with a facilitator is helpful.			12.5	50	37.5
c.	The signs help visitors understand the exhibit better.			25	50	25
d.	Visitors need more information to understand the exhibit.		25	50	25	
e.	I feel that learning occurs at this exhibit.			25	75	

Factor Analysis

The initial visitor survey identified three interpretable attitude factors:

- Liking Learning
- Atmosphere of the Science Center and Exhibit – Science City and the *Astronaut Training Center*
- Exhibit Theme – Space and Astronauts.

Items in the staff survey attitude factors were matched to those in the initial visitor survey. Mean responses to the follow-up questions from the attitude portion are shown in Table 6.7. In an effort to decrease the length of the survey and to focus on what facilitators feel visitors are retaining from their visit, some of the attitude factors were not represented in this survey.

Table 6.7: Mean Response to Factor Questions

Item		N	M	SD
Factor 2: Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and ATC				
4c	The signs help visitors understand the exhibit better.	8	4.0	0.76
3c	Reading the labels is useful to understanding the exhibit.	8	4.00	0.76
Factor 3: Attitude Toward the Exhibit Theme – Space and Astronauts				
3a	I feel the exhibit adds to visitors' understanding of an astronaut's experiences.	8	4.00	0.93

Table 6.8: Cronbach's Alpha of Reliability for Follow-up Survey Attitude Factors

Factor	N	M	SD	α
Factor 2: Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and ATC	2	4.00	0	1.00
Factor 3: Attitude Toward the Exhibit Theme – Space and Astronauts	8	4.00	0.93	--

Note: No questions from Factors 1 and 5 were included in the follow-up survey.

Factor analysis was not re-conducted with the staff attitude questions, due to the small data set involved. Cronbach's alpha of reliability was calculated for factors represented by multiple questions and the results are shown in Table 6.8. Staff responded identically to the two questions in the Atmosphere of the Science Center and Exhibit factor, causing the alpha value to be 1.

Inter-Factor Correlations and Correlations with Perception of Learning

The mean response to questions identified as part of the two Attitude Factors in the initial survey were correlated with the facilitators' perceptions of visitors' learning using the Pearson correlation coefficient. Two significant correlations were identified between the Attitude Factors and the facilitators' perception of visitor learning at the $p \leq 0.05$ level (Table 6.9). Feeling that learning occurs in the exhibit correlated with Attitude Toward the Science Center, $r\ (7) = 0.816$, $p = 0.013$.

Table 6.9: Correlations Between Facilitator Attitude Factors and Their Perception of Visitor Learning

		Factor	
		2	3
I feel that learning occurs at this exhibit.		0.816*	0.000
Factor	2 Science Center	1	0.204
	3 Exhibit Theme		1

* Correlation is significant at the 0.05 level (2-tailed).

Comparisons with Visitor Surveys

The visitor surveys were compared with the responses from the Science City facilitators to determine if the staff had the same perceptions of visitor behavior as the visitors themselves (Figure 6.1 and 6.2). Mean factor responses were compared using an independent samples *t*-test because the two measures were used for two different sets of individuals. The mean values of both the initial visitor survey and the follow-up visitor survey were compared statistically to the mean responses from the staff survey. Some factors were not represented in the surveys, so their means could not be compared in this analysis. Levene's test was evaluated to determine if statistically significant differences between the variances of the two groups was present. The results of the analysis are shown in Table 6.10 and 6.11.

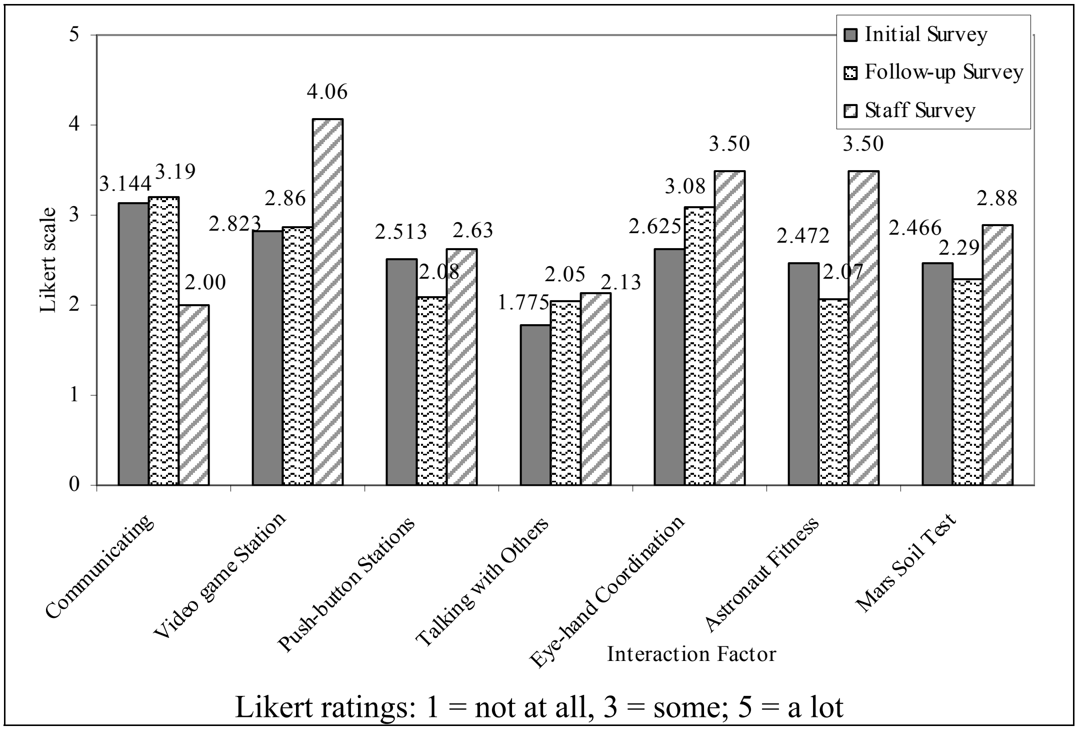


Figure 6.1: Mean Scores for Initial and Follow-up Surveys' Interaction Factors

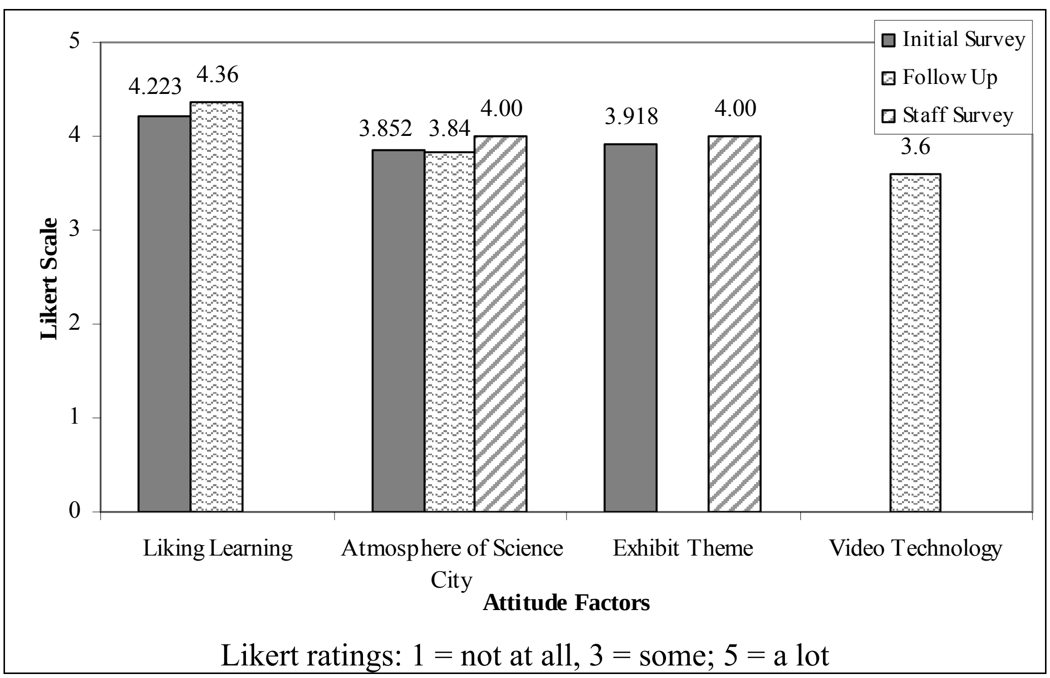


Figure 6.2: Mean scores for Initial and Follow-up Surveys' Attitude Factors

Table 6.10: Results of Independent Samples *t*-Test Using Initial and Staff Survey' Interaction and Attitude Factors

	Levene's Test for Equality	Sig.	Equal variance assumed	*t*	df	Sig.
Interaction Factor						
Communicating	4.33	0.04	No	3.01	13	0.01
Video Game Stations	0.88	0.35	Yes	-3.43	105	0.001
Push-button stations	8.44	0.00	No	-0.37	16	0.71
Talking with Others	0.57	0.45	Yes	0.83	101	0.41
Eye-hand coordination	2.79	0.10	Yes	-1.68	100	0.10
Astronaut fitness	1.17	0.28	Yes	-1.97	104	0.05
Mars Soil Test	7.93	0.01	No	-1.80	12	0.10
Attitude Factor						
Atmosphere of Science City	0.05	0.83	Yes	-0.57	106	0.57
Exhibit Theme	0.75	0.39	Yes	-0.38	106	0.71

Comparisons among the factor means for the initial and staff survey identified three statistically significant Interaction Factors: Communicating, Video Game Stations, and the Astronaut Fitness Test. No statistically significant differences were found among the Attitude Factors. For the Communicating Factor, Levene's test for equal variance resulted in a significant comparison at the $p < 0.05$ level, meaning that the assumption of the groups having equal variances was not valid. The non-standard *t*-test was significant, $t(13) = 3.01$, $p = 0.01$. The facilitators rated visitors as communicating (M = 2.58, SD = 0.43) less on average than what was indicated by the visitors (M = 3.12, SD = 0.92). The 95% confidence interval for the difference in means was large, ranging from 0.15 to 0.91. The eta squared index indicated that

7.8% of the variance of the communicating variable was accounted for by whether a visitor or facilitator was responding, a medium effect size.

For the Video game Station Factor, Levene's test was not significant at the $p < 0.05$ level, indicating that the variance within the two groups was similar. The *t*-test for differences was significant, $t\ (105) = -3.43$, $p = 0.001$. The facilitators rated visitors as using the Video Game Stations (M = 4.06, SD = 0.86) more on average than what the visitors perceived having done (M = 2.72, SD = 1.08). The 95% confidence interval for the difference in means was large, ranging from -2.12 to -0.57. The eta squared index indicated that 10% of the variance of the video game variable was accounted for by who were responding to the survey, a medium effect size.

The variance within the two groups, initial visitor survey and staff survey, was found to be equal for the Astronaut Fitness Test Factor. The *t*-test for differences was significant, $t\ (104) = -1.97$, $p = 0.05$. The facilitators rated visitors as using the Astronaut Fitness Test (M = 3.5, SD = 1.07) more on average than what the visitors perceived having done (M = 2.55, SD = 1.33). The 95% confidence interval for the difference in means was large, ranging from -1.91 to -0.004. The eta squared index indicated that 3.6% of the variance of the Astronaut Fitness Test variable was accounted for by who was responding to the survey, a small effect size.

Table 6.11: Results of Independent Samples *t*-Test using Follow-up and Staff Survey' Interaction and Attitude Factors

	Levene's Test for Equality	Sig.	Equal variance assumed	*t*	df	Sig.
Interaction Factor						
Communicating	4.03	0.06	Yes	1.33	20	0.20
Video Game Stations	0.28	0.60	Yes	-2.54	20	0.02
Push-button stations	8.42	0.01	No	-1.14	16	0.27
Talking with Others	0.26	0.62	Yes	-0.22	20	0.83
Eye-hand coordination	1.37	0.26	Yes	-0.63	19	0.54
Astronaut fitness	2.51	0.13	Yes	-2.20	20	0.04
Mars Soil Test	14.48	0.001	No	-1.32	19	0.20
Attitude Factor						
Atmosphere of Science City	0.11	0.74	Yes	-0.41	20	0.69

Comparisons between the follow-up visitor survey and the staff survey resulted in two statistically significant results in the interaction factors, Video Game Stations and Astronaut Fitness Test. No statistically significant differences between responses to the Attitude Factors were indicated. For the Video game Station Factor, Levene's test was not significant at the $p < 0.05$ level, indicating that the variance within the two groups was similar. The *t*-test for differences was significant, $t\ (20) = -2.54$, $p = 0.02$. The facilitators rated visitors as using the Video Game Stations (M = 4.06, SD = 0.86) more on average than what the visitors perceived having done (M = 2.86, SD = 1.17). The 95% confidence interval for the difference in means was large, ranging from -2.20 to -0.22. The eta squared index indicated that

24% of the variance of the video game variable was accounted for by who was responding to the survey, a large effect size.

For the Astronaut Fitness Test Factor, Levene's test was not significant at the $p < 0.05$ level, indicating that the variance within the two groups was similar. The *t*-test for differences was significant, $t\ (20) = -2.20$, $p = 0.04$. The facilitators rated visitors as using the Astronaut Fitness Test (M = 3.50, SD = 1.07) more on average than what the visitors perceived having done (M = 2.07, SD = 1.64). The 95% confidence interval for the difference in means was large, ranging from -2.78 to -0.07. The eta squared index indicated that 19% of the variance of the Astronaut Fitness Test variable was accounted for by who was responding to the survey, a large effect size.

Summary

The facilitators at Science City were surveyed to determine what they felt visitors were doing in the exhibit and what attitudes the facilitators held toward space, science, and the nature of science. Seventy-five percent of the responding facilitators felt that visitors were learning from the *Astronaut Training Center* exhibit.

Mean responses to the Interaction Factors were generally greater than visitor responses given in the initial and follow-up surveys for the factors: Video Game Stations, Push-Button Stations, Talking With Others, Eye-Hand Coordination, Astronaut Fitness Test, and the Mars Soil Test; the Communicating factor mean was lower for the facilitator survey than the two visitor surveys. Only differences between the Communicating, Video Game, and Astronaut Fitness Test factors were statistically significant at the $p < 0.05$ level between the initial and facilitator survey. The Video Game and Astronaut Fitness Test factors were statistically significant at this level as well for the comparisons between the follow-up visitor survey and the facilitator survey. Effect sizes were medium to large for these comparisons. No statistically significantly different results were found for comparisons among the Attitude factors.

A substantial portion of facilitators displayed a lack of understanding of the nature of science. Some could not identify the purpose of the exhibit, focusing on the need for visitors to gain content knowledge over positive attitudes toward science. As communicators of science, it is important for facilitators to understand the content being presented and the manner in which the content is presented. Many did not realize that the purpose of informal learning was not to instill content knowledge, a hard variable to measure but instead to instill positive attitudes and to encourage visitors to seek out other sources for content knowledge if desired.

A discrepancy also existed between the staff and the visitors' responses to both the Attitude and Interaction Factor questions. This may be due to no facilitators being present within the exhibit to help guide interactions toward the exhibit's purpose. Some guidance may increase the visitors' perceptions of learning. Future work could focus on examining the effect of a facilitator's interactions on visitors' perceptions of learning in informal environments. In the next chapter, the results of the Behavior Analysis will be discussed and compared to the survey results.

Chapter 7

Behavior Analysis

This chapter reports on observations of visitors' behaviors within Science City's *Astronaut Training Center.* Visitors' interactions were recorded on a rubric designed for use within the exhibit. This rubric was designed to track what exhibit stations people had higher frequencies of interactions in order to correlate actual usage with visitor responses on the initial and follow-up survey. The rubric was divided into three types of interactions: individual behavior, visitor conversation, and visitor interaction. Each interaction was then coded in regard to who was performing the behavior (attention) and whether the interactions were deemed active or passive.

Survey Collection

On days that observational data was collected, a sign was placed outside of the *Astronaut Training Center* to inform visitors that information regarding their behavior was being collected within the exhibit. This allowed the observer to be as non-obtrusive as possible during each visitor's interactions. While posting signs in front of an exhibit is common in museum research, Gutwell (2002) found that only 75% of visitors to an exhibit at the Exploratorium had read and understood the sign. Of the remaining visitors, some reported having felt bothered to some degree by the research occurring in the exhibit, but were not bothered enough not to enter the exhibit again. Gutwell raises the issue of whether or not visitors understand their rights not to participate in research enough to make informed decisions as whether or not to enter the exhibit being studied. For the purpose of this study and due to the limited number of entrances into the exhibit, it was felt that a sign gave an appropriate level of information for visitors to make informed decisions. The sign asked visitors to inform the researcher if they did not want to be included in the observational study. No visitors informed the researcher of their descent.

Visitors were randomly selected as they entered the *Astronaut Training Center* from the upper level of Science City. Visitors were followed within the exhibit and their behavior recorded on the Behavior Rubric (Appendix VI). Demographic variables, such as gender, ethnicity, age, and composition of the group were recorded based on observation. The day of the week and the length of interactions within the exhibit were also recorded. As visitors interacted with the exhibit, selected interactions were recorded on the rubric. The data was later compiled for analysis in SPSS.

Survey Sample and Demographics

Of the 98 groups surveyed as they went through the *Astronaut Training Center*, 147 adults and 295 children were tracked. Seventy percent of the adult visitors observed were females, while 51% of the children were female (Figure 7.1 and 7.2). Most of the visitors observed where White. Groups observed were split between family groups (44%) and those attending as part of a school group (45%). Thirty-seven percent of participants were between the age of 11 and 15, 16% between the age of 31 and 40.

The sample population for the behavior rubric was compared with the visiting population of Union Station (Blue Water Consulting Inc., 2002) in terms of the gender of the individuals in the group and their ethnicity using a Chi-squared analysis (Table 7.1). At the $p \leq 0.05$ level, a statistically significant difference was found for the gender distribution between the behavior sample and the visitors of Union Station, Chi-squared = 37.260, $p < 0.01$. A statistically significant difference was also found between the samples for the ethnicity variable, Chi-squared = 11.561, $p = 0.021$, which suggests that the sample used for observation was not reflective of the ethnicity of Union Station visitors.

Data was collected the most on Thursdays and Fridays and more visitors were tracked in the morning rather than the afternoon (Figure 7.4). This is a reflection of the visitor patterns seen at Science City. The majority of visitors are seen in the morning, with crowds dispersing around two in the afternoon. The mean visit to the exhibit of nine minutes was not reflective of the majority of visitors (Figure 7.5). Instead, the length of the visit for most visitors would be reflected best in the mode, three minutes. This is due to the few visitors who spent more than 20 minutes within the exhibit skewing the average.

Figure 7.1: Gender Distribution and Ethnicity of Adults in Visiting Groups

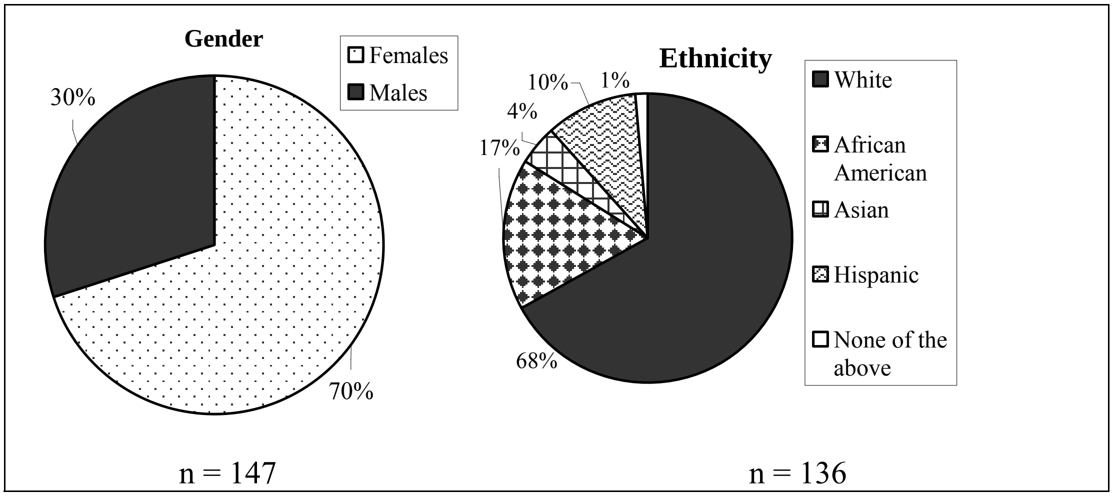


Figure 7.2: Gender Distribution and Ethnicity of Children in Visiting Groups

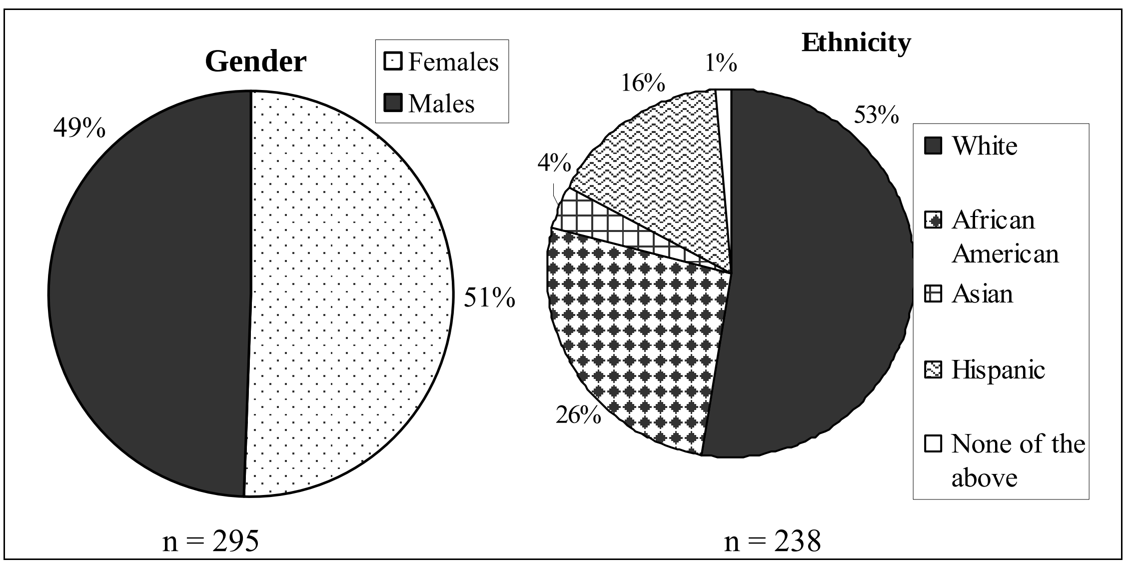


Figure 7.3: Age of Participants in Visiting Groups

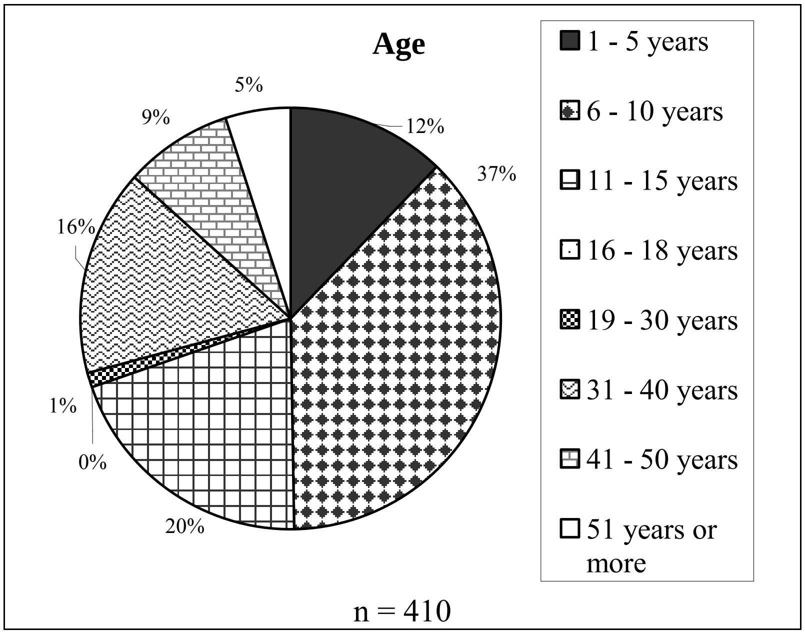


Table 7.1: Percentage Comparison of Science City Visitor Population and Study Sample

	Union Station[a]	This Study (n = 98)
Sex[b]		
Female	60	48
Male	40	88
Both males and females in group		57
Race/ethnicity[c]		
Caucasian	86	68
African American	9	17
Asian	2	4
Hispanic	2	10
Other		1

[a] From *Union Station Kansas City Demographics*, by Blue Water Consulting, Inc., 2002. Kansas City, MO.
[b] Chi-squared = 37.260; $p < 0.01$
[c] Chi-squared = 11.561; $p = 0.021$

Figure 7.4: Day of Visit

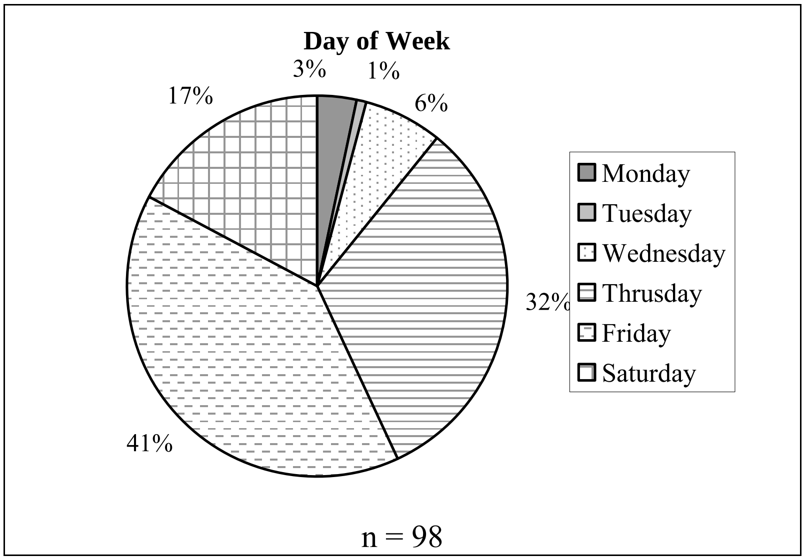
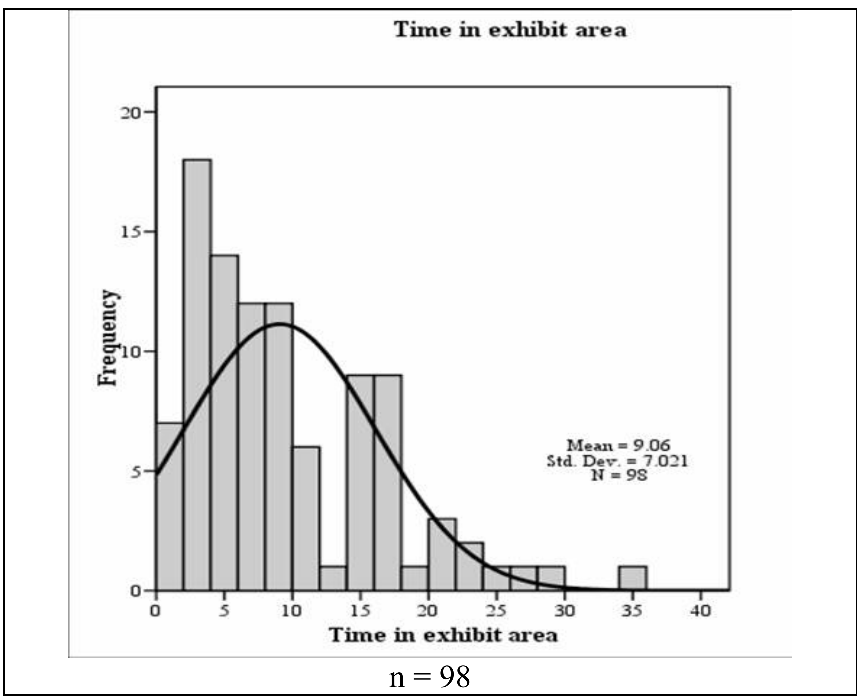


Figure 7.5: Length of Visit



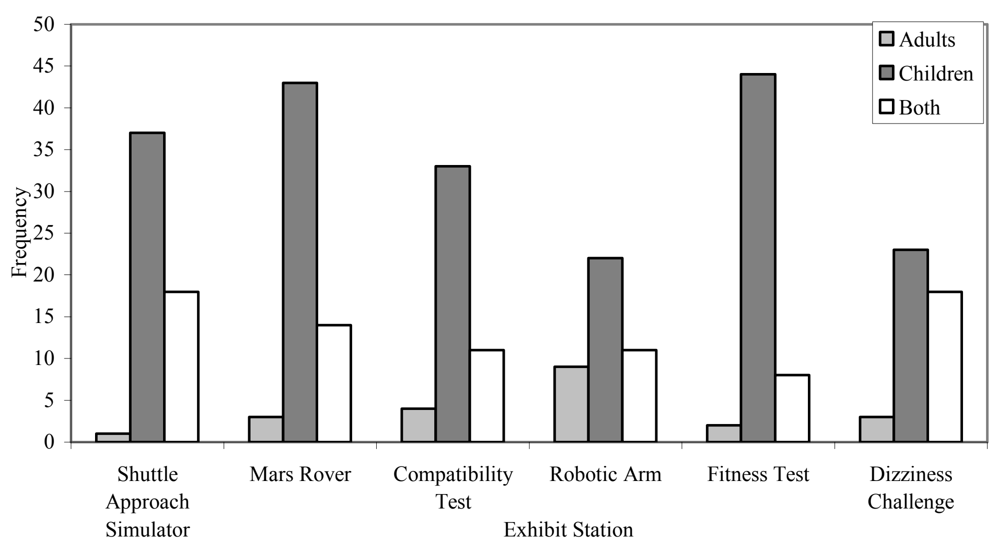
Visitor Behavior

To analyze the data obtained using the behavior rubric, many of the original variables were combined. For example, the data collected regarding pointing at stations originally was divided up into separate variables for each of the six stations: Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge. Data also initially indicated whether an adult or child was performing the action. These were combined to form a variable, pointing at a station, with the levels indicating at which station an individual pointed at (Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge, or multiple stations). A separate variable with three levels, adult, child, and both, was then created to indicate who was performing the action, reducing the original six variables to two variables. The data set went from 71 variables to 28 variables related to observable interactions within the exhibit. This allowed for most variables to contain enough data for further reduction using factor analysis.

Among all of the groups observed, visitors to the *Astronaut Training Center* interacted with all of the stations examined, in some manner. As separate levels, adults manipulated the Robotic Arm most frequently, while children most frequently manipulated the Fitness Test and Mars Rover (Figure 7.6). On instances when both adults and children from the same group were seen interacting with a station, they generally interacted with the Dizziness Challenge most frequently. Of the behaviors indicating a form of interaction, adults were seen pointing at the Shuttle Approach

Simulator the most, while children were seen pointing at the Mars Rover and the Shuttle Approach Simulator equally (Figure 7.7). Adults typically read the signage at the Compatibility Test, while children read the signage for the Dizziness Challenge (Figure 7.8). Adults most frequently called other members of their group over to the Dizziness Challenge, while children most frequently called others over to the Fitness Test (Figure 7.9). Children asked questions about the Robotic Arm and Compatibility test the most, while adults typically answered the questions regarding the Robotic Arm (Figure 7.10 & 7.11). Children, but not adults, expressed liking the exhibit stations, particularly the Mars Rover and the Fitness Test stations (Figure 7.12). One group of the 98 observed had both adults and children expressed a dislike, in this case related to the Mars Rover. Observation also revealed that children frequently watched other children interact with the exhibit stations (Figure 7.13).

Figure 7.6: Frequency of Exhibit Station Usage by Adults and Children



Number of groups = 98

Figure 7.7: Frequency of Pointing Behavior by Adults and Children at Each Exhibit Station

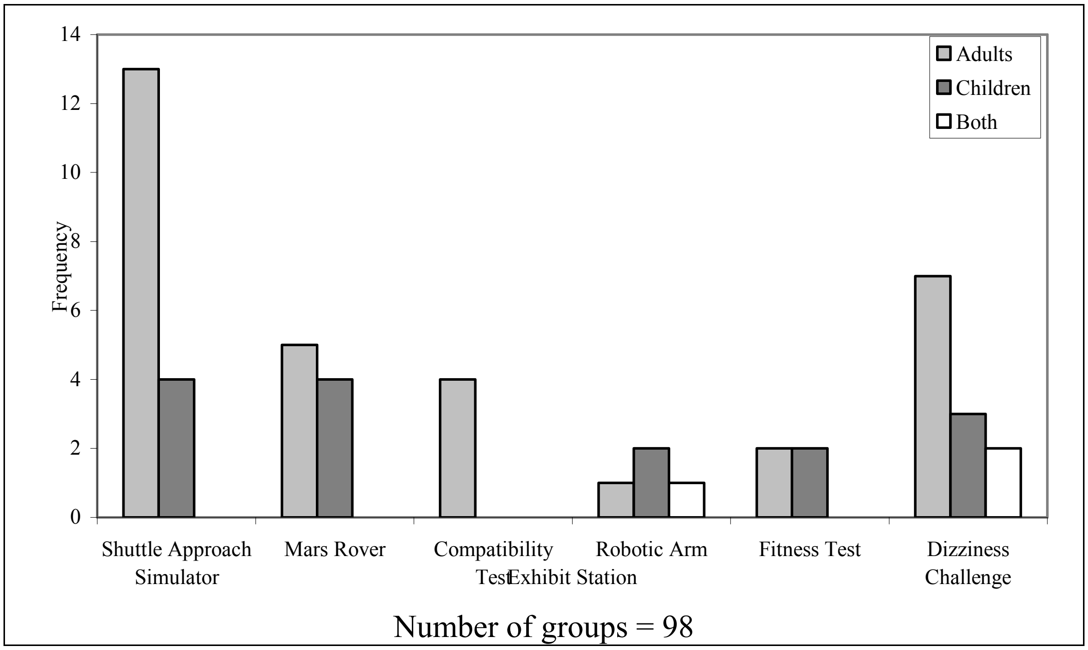


Figure 7.8: Frequency of Reading Signs by Adults and Children at Each Exhibit Station

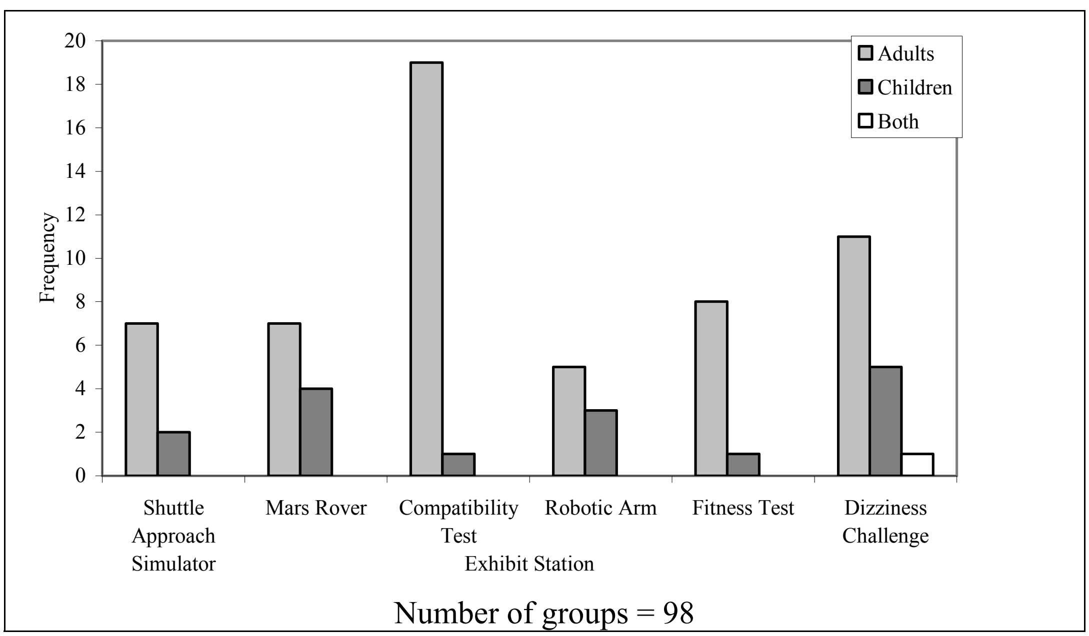


Figure 7.9: Frequency of Adults and Children Calling Someone Over to a Exhibit Station

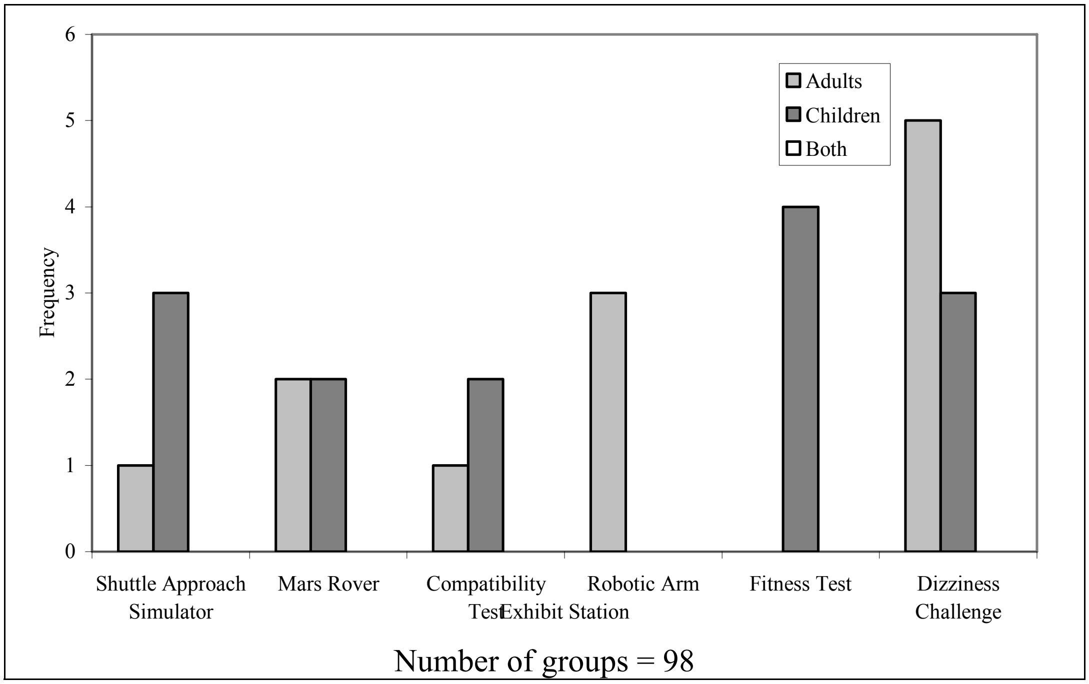


Figure 7.10: Frequency of Adults and Children Asking Questions about an Exhibit Station

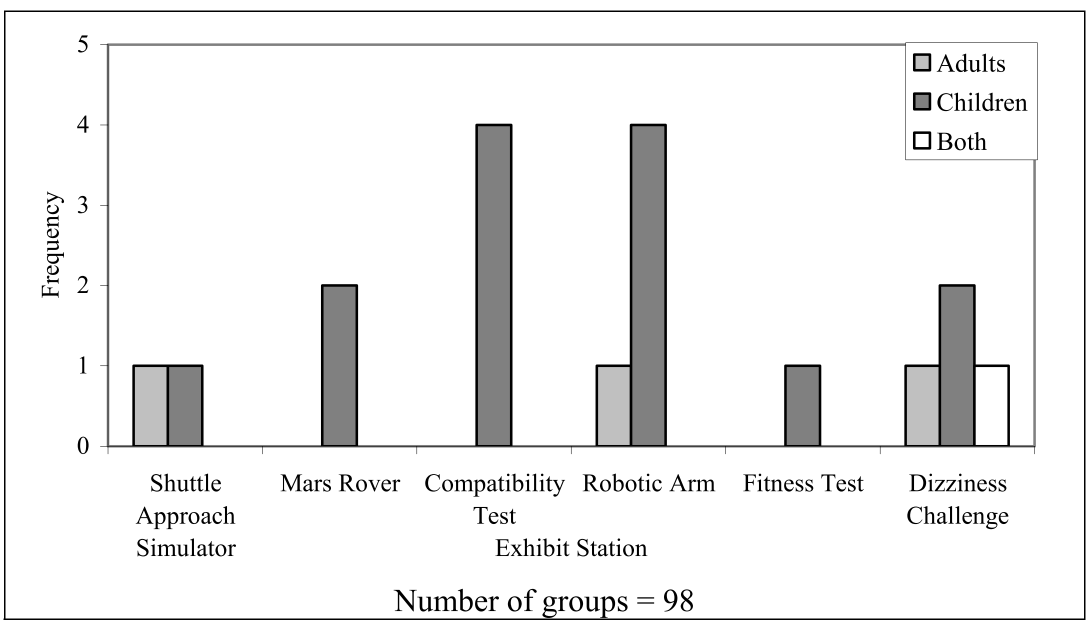


Figure 7.11: Frequency of Adults and Children Answering Questions about an Exhibit Station

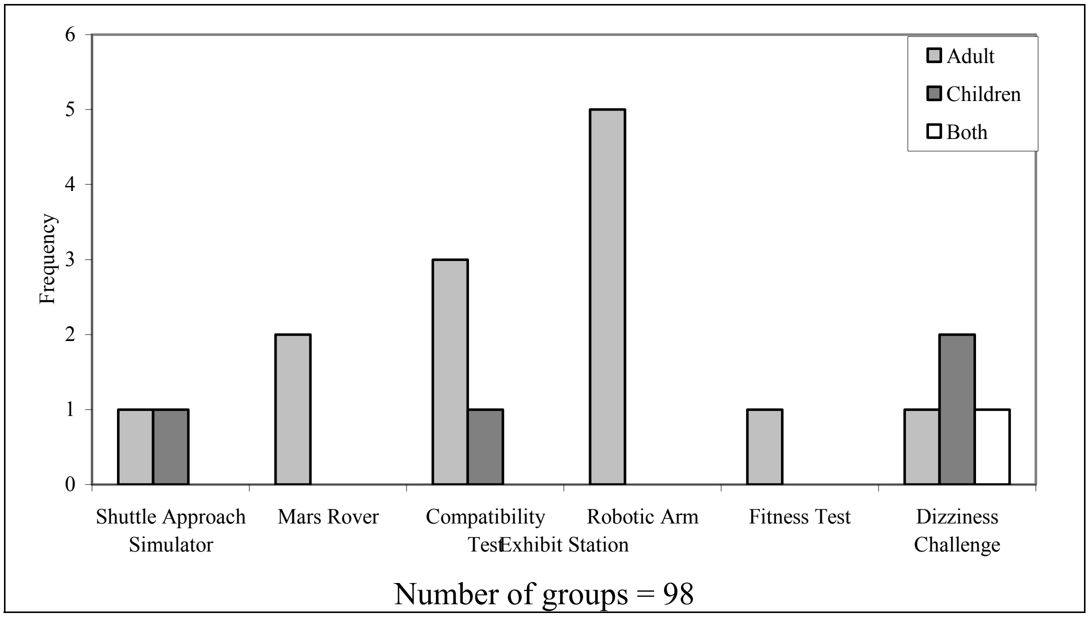


Figure 7.12: Frequency of Adults and Children Expressing Likes and Dislikes Related to an Exhibit Station

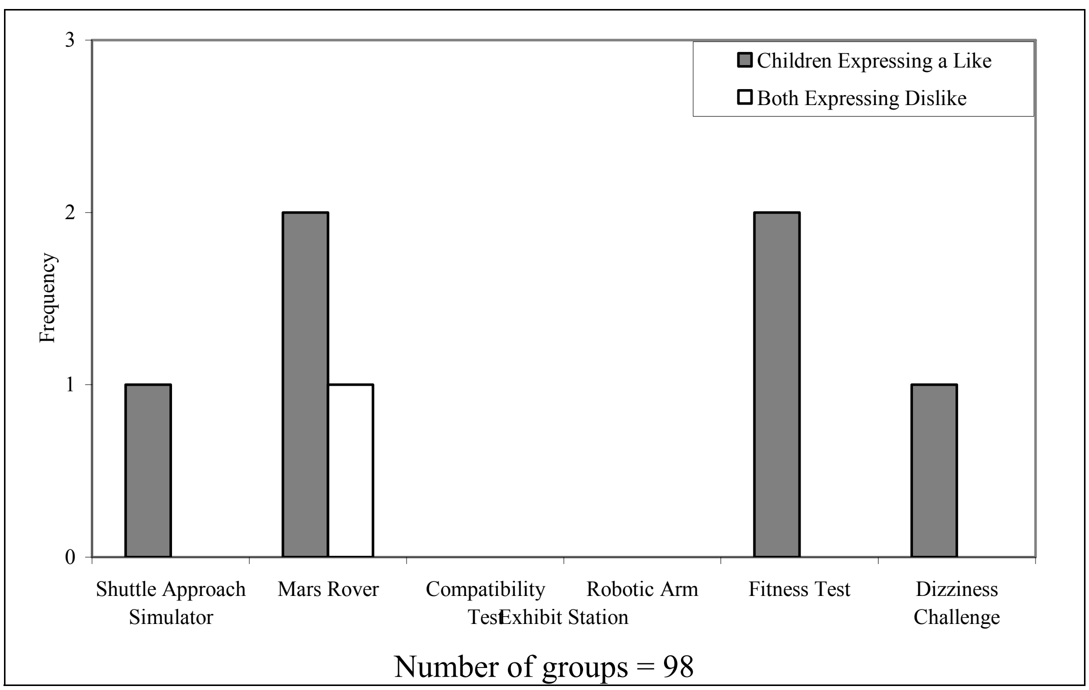
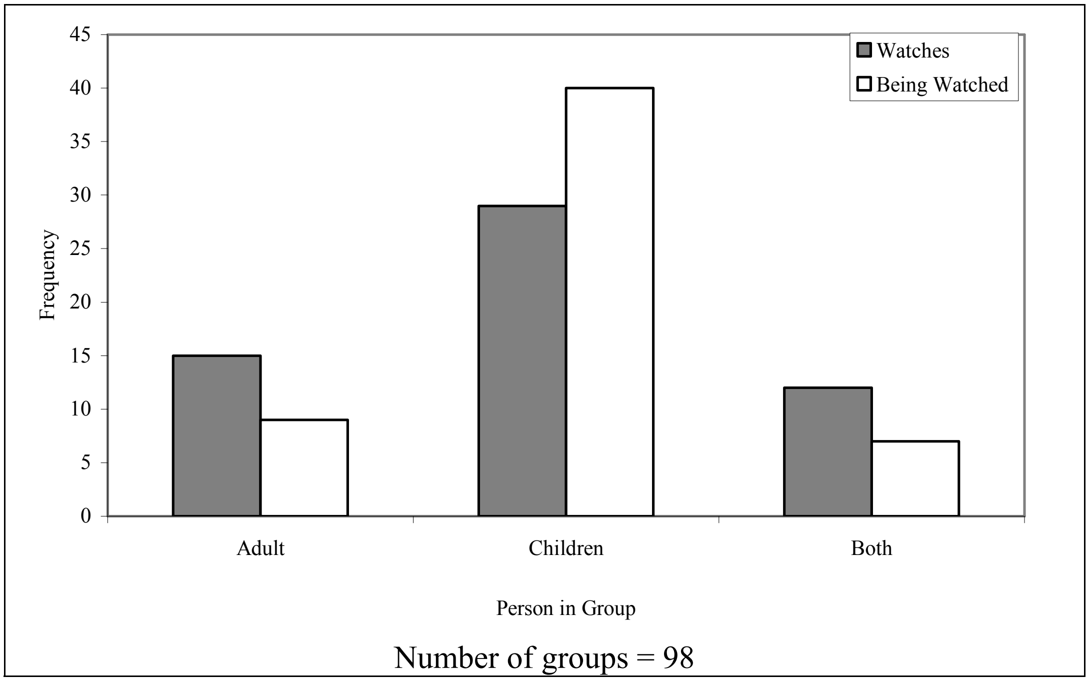


Figure 7.13: Frequency of Adults and Children Watching Others Manipulate an Exhibit Station



While describing how visitors interact with exhibit stations can be an indication of potential learning, what visitors choose not to do can also be informative. This information can be used to tailor exhibits toward a specific audience or to identify areas in need of improvement. Not all groups interacted with every station and often not all members of the group interacted with each station. Adults typically did not manipulate the Shuttle Approach Simulator but did point the simulator out to children (Figures 7.6. and 7.7). Children did not manipulate, call anyone over to, or express a like or dislike about the Robotic Arm (Figures 7.6, 9, & 12). Of the stations children asked questions about, they most frequently asked questions about the Robotic arm and the Compatibility Test. So, while children were curious about the Robotic Arm, they did not attempt to explore the station by interacting with it.

Relationships Among Observed Behaviors

A two-way contingency table analysis was conducted to evaluate whether any relationships existed among the identified behaviors. Contingency tables evaluates whether statistical relationships exist between two variables containing nominal or ordinal data (Green & Salkind, 2003). The analysis focuses on the cell frequencies to evaluate whether the table's rows and column variables are related. This analysis is typically used to evaluate three types of studies: independence between variables controlling the total number of participants, homogeneity of proportions where subjects can be sampled from different populations, and unrelated classifications where the total number of subjects in each row and column are the same. This study looks at the independence between variables. Two major assumptions underlie the two-way contingency tables. The first assumption is that observations for a two-way contingency table are independent of one another. This assumption is designed to reduce dependency in the data. The second assumption is that the analysis will yield a test statistic that is approximately distributed as a Chi-squared when the sample size is very large. For a sample to be distributed as a Chi-squared, the number of categories would need to increase as the observed χ^2 increases (Shavelson, 1996, p. 556). The distribution of data would also need to be unimodal and positively skewed. For tables that contain more than one level within the row or column, concern should arise if more than 5% of the cells have frequencies less than five.

The analysis produces three effect size estimates of use to this analysis: Pearson correlation coefficient for 2 x 2 analyses, phi, and Cramér's V. Like the Pearson correlation coefficient, phi ranges from -1 to +1, where values close to zero indicate a weak relationship and values closer to ±1 indicate a very strong relationship. The sign on the coefficient has no direct meaning for qualitative variables as used in this analysis. Cramér's V is a rescaled version of phi such that the range is from 0 to 1. For 2 x 2, 2 x 3, 3 x 2 tables, phi and Cramér's V are identical.

Seven statistically significant results were found in the eighteen analyses conducted. Each statistically significant result will be discussed individually. The first comparison consisted of two variables, the station to which visitors were pointing with the station for which visitors were reading the signage, both with eight levels corresponding to no interactions and the seven stations examined (Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge). Pointing at the station and reading the signage at the station was found to be significantly related, Pearson χ^2 (42, N = 98) = 71.419, p = 0.003, Cramér's V = 0.003. Follow-up pairwise comparisons were conducted to evaluate the difference among these proportions. The Holm's sequential Bonferroni method was used to control for Type I error at the 0.05 level across all 28 comparisons. The only pairwise difference that was significant was between no pointing at exhibit stations and pointing at the Mars Rover across all levels of reading signage at exhibit stations. Further follow-up tests were conducted to determine which level of reading signage was the source of the significance following the same method as before. This resulted in the only pairwise comparison being significant being between not reading the signage and reading the signage at the Mars Rover. The probability of a visitor reading the Mars Rover's signage was about 18 times more likely when the visitor also pointed at the rover's station.

The second significant comparison conducted evaluated whether calling someone over to a station was more likely at a particular station. The two variables were who called someone over with three levels (adult, child, or both) and the station where this occurred, with eight levels (no calling, and the seven stations examined: Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge). Who called someone over and the station where this occurred was found to be significantly related, Pearson χ^2 (21, N = 42) = 194.8, $p \leq 0.01$, Cramér's V ≤ 0.01. After not calling someone over, children typically called someone over to an exhibit station more than adults. The follow-up comparisons yielded no statistically significant results using the Holm's sequential Bonferroni method.

The third significant comparison evaluated whether a relationship existed between an individual saying they liked a station and the station to which they were referring. The two variables were the individual who expressed a like with three levels (adult, child, or both) and the station to which they were referring with eight levels (Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge, and not expressing a like or dislike). The person who expressed liking the station and the station in question was found to be significantly related, Pearson χ^2 (4, N = 98) = 98.00, $p \leq 0.01$, Cramér's V ≤ 0.01. Children expressed liking an exhibit station, though adults did not verbally express this sentiment. The follow-up comparisons yielded no statistically significant results using the Holm's sequential Bonferroni method.

The fourth significant comparison evaluated whether a relationship existed between two individuals who were exhibiting non-exhibit related behavior. The two variables, person 1 and person 2, had three levels: adult, child, or both. Who was participating in this type of behavior was found to be significantly related, Pearson χ^2 (1, N = 18) = 7.901, p = 0.005, Cramér's V = 0.005. Follow-up pairwise comparisons were conducted to evaluate the difference among these proportions. The Holm's sequential Bonferroni method was used to control for Type I error at the 0.05 level across all three comparisons. Only one significant pairwise comparison was found between the two individuals. The probability of the person being an adult exhibiting this behavior is six times higher than when the first individual is a child, while the behavior is much less probably when it is occurring between two adults.

The fifth significant comparison evaluated whether a relationship existed between an individual asking a question and the station about which they were asking. The two variables were who asked a question, with three levels (adult, child, or both) and the station to which they were referring with eight levels (Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge, and not calling someone over, and no questions asked). The person who asked a question and the station about which they were asking was found to be significantly related, Pearson χ^2 (18, N = 98) = 133.389, $p \leq 0.01$, Cramér's V ≤ 0.01. After no one exhibiting the behavior, children were more likely to ask a question about a station than adults. The follow-up comparisons yielded no statistically significant results using the Holm's sequential Bonferroni method.

The sixth significant comparison evaluated whether a relationship existed between an individual answering the question and the station with which the question referred. The two variables were the individual who answered the question with three levels (adult, child, or both) and the station to which they referred with eight levels (Shuttle Approach Simulator, Mars Rover, Compatibility Test/Make Repairs, Robotic Arm, Fitness Test, and Dizziness Challenge, and not calling someone over, and no behavior). The person who answered the question and the station asked about was found to be significantly related, Pearson χ^2 (18, N = 98) = 191.800, $p \leq 0.01$, Cramér's V ≤ 0.01. After lack of the behavior, adults more frequently answered questions regarding the stations. The follow-up comparisons yielded no statistically significant results using the Holm's sequential Bonferroni method.

The seventh significant comparison evaluated whether a relationship existed between an individual asking a question and the individual answering the question. The two variables were the individual who asked the question and the individual who answered, both with three levels (adult, child, or both). The person who asked the question and who answered the question was found to be significantly related, Pearson χ^2 (9, N = 98) = 155.750, $p \leq 0.01$, Cramér's V ≤ 0.01. Not performing the behavior was seen most frequently, though generally children asked questions of adults the most. The follow-up comparisons yielded no statistically significant results using the Holm's sequential Bonferroni method.

Factor Analysis

Factor analysis was conducted on the observable behaviors and demographic variables with variances greater than 0.5 using the maximum likelihood method. The variance level provided the minimum amount of variance needed to obtain interpretable, rotated results. The rotation was conducted using the Varimax method and resulted in eight interpretable factors (Table 7.2):

- Station Usage
- Calling Someone Over
- Group Factor
- Station Interest
- Ethnicity
- Kids
- Age of Adults
- Person Called to a Station

Questions were deemed in a factor if the factor loading values were ±0.3 or greater. This allowed all of the variables to be placed within a factor. The factors account for 55% of the total variance found in the behavior data. The first factor, Station Usage, focuses on the stations visitors manipulated, signs they read, with what station they watched other visitors interact, and the time they spent in the exhibit as a whole. This factor accounted for 15% of the total variance. The second factor, Calling Someone Over, incorporates the behavior of calling another visitor over to view the station and the station of interest. This factor accounted for 7% of the variance. The third factor, Group Factor, relates to some of the group dynamics, such as the number of adults present, the age of the children in the group, the composition, and the day of the week for the visit. This factor accounted for 7% of the variance. The fourth factor, Station Interest, describes behaviors such as pointing and expressing liking a station as interest in the station. This factor accounted for 6% of the variance. The fifth factor, Ethnicity, accounts for 5% of the total variance. The sixth factor, Kids, relates to the number of kids and their ages within the group. This factor accounts for 5% of the total variance. The seventh factor, Age of the Adults, accounts for 5% of the total variance. The final factor, Person Called to a Station, is whether the person who is called to a station is an adult or a child. This factor also accounts for 5% of the total variance.

Table 7.2: Factor Analysis of Visitor Interaction Questions on Initial Visitor Survey								
Behaviors	Factors Ranked by Loading Magnitude							
	1	2	3	4	5	6	7	8
Factor 1: Station Usage								
Time in exhibit area	0.79	0.08	0.12	0.17	-0.15	-0.15	-0.05	0.00
Manipulates Compatibility Test	0.65	-0.18	-0.11	-0.07	0.12	-0.08	0.03	-0.06
Manipulates Dizziness Challenge	0.64	0.07	0.09	0.23	0.03	0.11	0.06	0.19
Follows exhibit sequence	0.59	-0.06	0.02	-0.11	-0.02	0.16	0.12	-0.00
Station signs being read at	0.57	0.10	0.03	0.16	-0.12	-0.10	-0.10	-0.09
Manipulates Fitness Test	0.57	-0.01	0.14	0.24	-0.07	0.06	-0.00	0.19
Station being watched	0.54	0.09	0.04	0.06	0.15	0.02	0.05	0.07
Manipulates Robotic Arm	0.48	-0.23	0.14	0.28	0.07	0.00	-0.08	0.16
Manipulates Shuttle Simulator	0.45	-0.03	-0.01	-0.03	-0.07	0.08	0.19	0.10
Manipulates Mars Rover	0.42	-0.01	0.03	0.21	-0.20	0.06	-0.13	0.16
Factor 2: Calling Someone Over								
Calls someone over	-0.00	1.00	0.03	0.00	0.06	-0.01	-0.00	-0.03
Station involved	-0.00	0.87	0.04	0.08	0.03	-0.02	-0.02	0.12
Factor 3: Group Factor								
Composition of group	-0.19	-0.08	-0.69	0.00	0.25	0.14	-0.21	0.01
Day of Week	-0.11	-0.03	0.57	-0.06	0.10	0.02	-0.06	-0.00
Number of Adults in Group	0.28	0.05	0.51	-0.09	-0.02	-0.01	0.12	-0.02
Age of kids	0.28	0.07	0.43	-0.13	-0.02	0.33	0.19	-0.20
Factor 4: Station Interest								
Person Pointing at any station	-0.06	0.18	-0.29	0.86	0.21	-0.01	0.11	-0.28
Station being pointed at	0.21	-0.00	0.11	0.42	0.16	0.01	-0.02	0.08
Station liked	0.14	-0.00	-0.16	0.37	-0.06	0.03	-0.05	0.13
Station question asked about	0.26	0.01	-0.27	0.31	-0.13	-0.02	0.10	0.13
Factor 5: Ethnicity								
Ethnicity of children	-0.03	-0.00	-0.38	-0.02	0.91	0.14	-0.05	-0.08
Ethnicity of adults	-0.02	0.07	0.16	0.13	0.52	0.01	-0.04	-0.01

Behaviors	Factors Ranked by Loading Magnitude							
	1	2	3	4	5	6	7	8
Factor 6: Children								
Number of children in group	0.05	-0.06	-0.40	0.06	0.16	0.89	-0.07	-0.02
Gender of children	0.01	-0.00	0.09	0.01	0.01	0.42	0.04	-0.03
Factor 7: Age of Adults								
Age of adults	0.08	-0.02	0.18	0.02	-0.01	0.05	0.98	0.05
Factor 8: Person Called to a Station								
Person called over	0.30	0.11	-0.12	0.09	-0.07	-0.13	0.08	0.92

Cronbach's alpha of reliability was computed for the eight factors identified. The means, variance, and alpha values are shown in Table 7.3. Most factors had moderate reliability, with the exception of the Group and Ethnicity Factors. The negative alpha value found for the Group Factor, indicates that assumptions in the reliability calculation were violated. If the composition of the group item was deleted from this factor, the reliability would increase to 0.434. The remaining three items, day of week, number of adults in the group and the age of the kids would be the composition of the group and would indicate whether the group was a family, school group, or a group of friends. Reliability between the Ethnicity items for adults and children had the poorest reliability of the items examined. It is unclear why the Ethnicity factor had such a low reliability.

Table 7.3: Cronbach's Alpha of Reliability for Observed Behavior Factors

Factor	α	N	M	Variance
Station Usage	0.668	10	3.08	
Calling Someone Over	0.728	2	0.69	0.184
Group Factor	-0.248	4	2.30	0.437
Station Interest	0.504	4	1.63	2.715
Ethnicity	0.073	2	2.40	0.917
Kids	0.446	2	2.57	0.576
Age of Adults	-	1		
Person Called to a Station	-	1		

<u>Comparisons with Initial, Follow-up and Staff surveys</u>

While factor analysis resulted in eight meaningful variables describing the nature of visitors' interactions within the *Astronaut Training Center*, combining the ordinal data into a mean value for quantitative comparison with the initial and follow-up visitor survey and the staff survey would prove fruitless and result in loss of much of descriptive nature of the data set. Data collected on the surveys was done using a different metric than that of the behavior analysis. As such, comparisons between the surveys and behavior analysis will be done qualitatively where appropriate.

Gender and ethnicity of visitors within the survey and behavior populations were previously compared (see above, Survey Sample and Demographics). Age of the children within the groups surveyed was also compared using a Chi-squared analysis (Table 7.4). A statistically significant difference was found between the ages of children in the initial visitor survey and the follow-up visitor survey, Chi-squared = 15.537, p = 0.001. The age of participant was not a variable collected during the follow-up survey.

Table 7.4: Percentage Comparison of Science City Visitor Population and Study Sample

Age group[a]	Initial Visitor Survey	Behavior Analysis
1-5	20	13
6-10	70	37
11-15	21	24
16-18	17	0

[a] Chi-squared = 15.537; $p = 0.001$

Three common behaviors were prevalent through out the initial and follow-up survey and the behavior analysis: reading signage, talking about the exhibit, and interactions with exhibit stations whether by simple usage or active manipulation. Across the three instruments, interactions with the Shuttle Approach Simulator and Mars Rover were more prevalent than with other stations. Staff also rated the usage of these two stations higher than other stations. Reading signage was also seen to occur, with 88% in the initial and 69% in the follow-up survey respondents indicating that they had read the signage. This value was confirmed through observation, as 52% of the groups surveyed had individuals reading the signage out-loud to other members of their group. This value may be higher if individuals who read the signage to themselves where included as well. The initial visitor survey did not specify if the reading was done out-loud or silently.

The degree of socialization related to the exhibit was also rated high in all of the surveys. Sixty-three percent of visitors completing the initial visitor survey indicated having talked about the exhibit, 61% in the follow-up survey. Observation found that 26% called someone over to an exhibit and 7% of visitors expressed a like or a dislike. Twenty percent of those observed performed explicit behaviors not associated with the exhibit. Results from the staff survey also disagreed with the perception of how much visitors talk about the exhibit, rating the visitors' socialization from not at all to some. This indicates that the self-reporting of the degree of socialization among visitors may have been inflated on the initial and follow-up survey.

Summary

Visitors to the *Astronaut Training Center* at Science City were observed as they interacted with the exhibit. Behaviors were recorded on the Behavior Rubric, a rubric tailored to describe the interactions of visitors at specific stations within the exhibit. Interactions included pointing at a station, reading the station's signage, calling someone over, asking a question, expressing a like or dislike, watching other visitors, or manipulating an exhibit station. The level of non-exhibit related behavior was also recorded. The relative age (adult, child, or both) was recorded.

The sample of visitors observed for the behavior analysis was compared with the visiting population at Union Station and found to be statistically significantly different in regard to gender and ethnicity, based on a Chi-squared analysis. This sample population also differed by age when compared with individuals completing the initial visitor survey (Table 7.4). This suggests that the sample of visitors observed is not reflective of those studied previously in regards to these two variables.

Qualitative comparisons were made between the behavior analysis and initial and follow-up visitor survey and staff surveys. This revealed some discrepancies between the behaviors observed and the level of interaction perceived by staff and visitors. For instance, talking about the exhibit was rated high on the initial visitor survey, but was reported to be much lower by staff and observation confirmed approximately 20% of those observed participated in this type of behavior. This discrepancy may be due to the differences in populations being studied or an over-estimate of interaction by visitors completing the survey.

The frequency of station usage was observed to correspond to that reported by visitors and staff. The Shuttle Approach Simulator and the Mars Rover stations had higher frequencies of usage by children than stations such as the Robotic Arm or Dizziness Challenge. In the next chapters, a discussion of the results of the three surveys and behavior analysis are presented. In the chapter following, some of the implications for exhibit development are presented.

Chapter 8

Discussion and Implications for Development of a Chemistry Exhibit

This chapter contains an analysis of the results from the two visitor surveys, the staff survey, and the behavioral analysis. The following chapter reports three potential chemistry exhibits developed using some of the salient features associated with learning from this research.

Discussion and Implications

Eighty-six percent of visitors to the *Astronaut Training Center* at Science City felt they had learned from their experiences during their visit. Forty-one percent of visitors described what they learned with short responses, such as “Mars info.” While visitors did not describe in depth their learning, Science City facilitators were split over what they felt visitors learned from the exhibit, though the majority of the facilitators felt visitors learned from the experience. While visitors held this intrinsic view, correlations between visitors’ perceived learning and the seven identified interaction factors: Communicating, Video Game Stations, Push-Button Stations, Talking with Others Outside the Group, Eye-Hand Coordination, the Astronaut Fitness Test, and the Mars Soil Test, were not statistically significant. This result is not surprising, as no study has been able to link observable behaviors in the museum with an independent measure of learning (Borun et al., 1996; Dierking & Falk, 1994). Some visitor attitudes showed a statistically significant relationship to visitors’ perception of learning. These attitudes include feeling positive toward the exhibit, adding to the visitor’s understanding of astronauts’ experiences, finding space travel interesting, and learning about Mars. While visitors may have held these attitudes prior to their visit, comparison of the mean difference scores between the initial visitor survey and the follow-up visitor survey indicates no statistically significant difference in attitude between the two surveys. Visitors' attitudes toward science and space, therefore, remained relatively constant and positive for a period of time after their visit. This study did not attempt to address whether these attitudes where held prior to the exhibit and brought about by positive prior experiences relating to the content.

Initial and Follow-up Visitor Survey

The factor analysis conducted in the initial visitor survey resulted in seven interpretable factors related to visitor interactions with the exhibits. Cronbach's alpha of reliability for the seven interaction factors was strong, ranging from 0.75 to 0.90. While no statistically significant correlation was seen between the interaction factors and perception of learning, significant correlations were seen among the individual factors. For example, the Communication factor correlated significantly with Video Game Stations, Push-Button Stations, Talking with Others Outside the Group, and use of the Astronaut Fitness Test. If visitors manipulate a specific station, whether the station contains buttons to push, tasks to control via video technology, or involves increased physical activity, visitors may be more likely to talk about their experiences. From a constructivist perspective, if visitors can be encouraged to talk about their experiences, an increase in visitor learning is more likely to occur. Being able to tap into visitors' perceptions of their increase in knowledge is a challenging task in informal environments, due to the large number of variables encountered and lack of ability to construct a standardized content knowledge base with which all visitors interact. By being able to identify behaviors that are linked to or encourage learning, researchers can use non-obtrusive behaviors to better study learning within these environments and develop more effective exhibits.

Video Game Stations also correlated moderately with other interaction factors: Push-Button Stations, Talking with Others Outside the Group, use of the Astronaut Fitness Test, and use of the Mars Soil Test. Looking only at correlations with the Push-Button Stations, use of the Astronaut Fitness Test, and use of the Mars Soil Test factors, comparison of the exhibits within the factors reveal some physical similarities with the Mars Rover and Shuttle Approach Simulator. For instance, both the Shuttle Approach Simulator and Mars Rover use joysticks to change how the user is interacting with the video environment. For the Shuttle Approach Simulator, this would mean adjusting the angle of descent onto the runway, for the Mars Rover, controlling the direction the rover is moving. The Mars Soil Test also uses a type of joystick to rotate the sample being examined by the visitor. Visitors can use a ball mouse to change the experiment being run on the sample, as well as video technology to simulate taking measurements of radioactivity, water content, and magnetism. The use of video technology in this case also ensures that a waste stream is not produced over multiple uses by many visitors.

Similarly to the Shuttle Approach Simulator and the Mars Rover, the Astronaut Fitness Test requires visitors to manipulate a variable to produce an outcome. In the case of the Astronaut Fitness Test, visitors have to pedal a bicycle to increase their heart-rate. For the Shuttle Approach Simulator, visitors manipulate a simulated space shuttle and attempt to successfully land it. With the Mars Rover, visitors have to move the rover around a simulated Martian surface. The incorporation of multiple aspects of the other stations into the Shuttle Approach Simulator and the Mars Rover may be a source of their popularity among visitors. If visitors liked manipulating the station with a joystick or receiving immediate feedback from the station via a computer program, visitors would also find these exhibits more interesting and, thus, be more involved. By intentionally designing exhibits to include both manipulating a joy-stick and receiving feedback via a computer program, exhibit designers may be able to increase the popularity of a specific exhibit station, thereby increasing visitor learning.

A more complex station may also drive the need for visitors to ask more questions of other visitors, to get an idea of what the program does and what to expect from using it. As visitors ask more questions, they put forth their understanding of the exhibit and communicate with others until everyone can reach a consensus on the meaning of the exhibit station. Through stimulating conversations, interaction among visitors would increase, thereby increasing the potential for conversation leading visitors to construct new knowledge. While this may lead to some visitors constructing knowledge that is contrary to how trained scientists view the material. The literature on learning in science museums has not begun to address what misconceptions visitors may be coming away with after interacting with exhibits.

Reading the exhibit signage can also lead visitors toward the path of constructing new knowledge through discussing the exhibit content. Correlations existed that suggested that visitors who read the signage felt the signage was helpful and did what the signs suggested. While this was not directly correlated with the visitors' perception of learning, it suggests that visitors can be guided into behaviors that increase opportunities for learning due to the value visitors place on finding the information they desire within the posted signs. This trend continued in the follow-up survey with visitors rating having read the signs in the exhibit highly positive. Science City staff members, in contrast, did not feel that visitors were reading the signage and the survey did not ask the staff to elaborate on why they felt that way. Contrary to staff perspective, observation of the visitors during the behavior analysis supported the visitor responses, particularly when adults were reading the signage aloud.

While the Shuttle Approach Simulator was popular among visitors, concern arose over whether visitors viewed this station, with its arcade-like appearance complete with pilot's seat and graphical representation of knobs and buttons in the cockpit, as being a place for play and not learning. Questions within the follow-up survey addressed these concerns. The follow-up surveys indicated that visitors felt that computer technology is a valuable learning tool (79%), though fewer felt that video games were learning tools (50%) and even fewer still indicated that the computer simulations within the exhibit helped them feel more like an astronaut (36%). Visitors' attitudes toward the use of this type of technology were found to relate to their over-all Attitudes Toward Liking Learning, the Science Center and the Exhibit. Generally, those who feel positively toward the use of video technology in learning environments hold positive attitudes toward these factors. A correlation also existed between the interaction factors, Video Game Stations and visitor's attitudes toward the use of video technology. Visitors who interacted with the video game technology had more positive responses for attitudes toward use of this technology as a learning tool. This suggests the potential to affect a change on visitor's attitudes if they are willing to interact with the exhibit. If an interactive video can be designed to attract visitors to the station and encourage their interaction, visitors may show more positive attitudes toward learning science and potentially induce learning on the part of the visitor through increasing positive attitudes.

Level of immersion is also thought to play a role in how visitors interact with the exhibit station. Comparison between visitor responses to the manipulating and interacting with stations questions resulted in two significant *t*-test results (see Table 4.1). Two stations, the Shuttle Approach Simulator and the Astronaut Fitness Test, allowed visitors to become immersed in the station. In the case of the Shuttle Approach Simulator, a video monitor was encased in an arcade-like façade in which the visitor sits in a cockpit and moves the joystick to land the shuttle as seen on the video monitor. The Astronaut Fitness Test involves pedaling a bicycle to increase the visitor's heart rate. Both stations require the visitor to sit in order to participate in the station's activity. By sitting within the exhibit station, visitors may feel more immersed and thereby become more engaged with the station's content. This may have led people to respond as having interacted more with these stations than with the exhibits which contained separate stools. Part of the experience of interacting with the station may be lost in having to position the stool in front of the station or, alternatively, visitors may not feel as invited to spend more time with stations containing stools than with build-in seats.

The important role of the Shuttle Approach Simulator and Mars Rover keeps reappearing in the surveys. Visitors typically ranked having manipulated these exhibit stations higher than any of the other stations examined (Figure 4.7 and Table 5.2). Visitors' perception of their manipulation was reflected in both the observations of facilitators (Table 6.1) and observations conducted by the researcher (Figure 7.6). These two stations offer the highest number of ways for visitors to interact meaningfully in order to produce behaviors associated with learning. If an exhibit can be designed to incorporate the aspects of these stations that have been associated with increasing the potential for visitor learning, some of the popularity of this exhibit may be captured and used within a new exhibit.

Examining the responses to the open-ended questions regarding what visitors learned from their experiences within the exhibit, visitors generally used short, descriptive responses. Statements such as "the bathroom was cool" or that the "rover was hard to handle" were typical. Fewer visitors admitted that life in space can be "challenging," signifying that they were meshing their current experiences with prior ones as they attempt to apply meaning to their current situation. Most of the shorter responses seen could be due to factors such as lack of time, interest, or not consciously identifying the knowledge gained from their personal experiences. The time needed for visitors to digest new learning can affect the outcome of single-instance surveying in informal settings (Falk, 2001b). The follow-up survey was intended to capture knowledge held by visitors that had not had the time needed to be translated into meaningful content knowledge prior to the initial survey.

A second factor analysis was conducted on the attitude questions to determine if any patterns existed in responses. This yielded three interpretable attitude factors: Attitude Toward Liking Learning, Attitude Toward the Atmosphere of the Science Center and Exhibit – Science City and the *Astronaut Training Center*, and Attitude Toward Exhibit Theme – Space and Astronauts. Cronbach's alpha of reliability for these factors was strong, ranging from 0.58 to 0.68. This indicates that the items within the factor yield predictable results based on the pattern of visitor responses.

Visitors' attitudes toward science and space were positive on both the initial and follow-up survey (Figure 5.4). Positive attitudes toward talking about the exhibit reflected those seen in the interaction section of the survey (Figure 5.3). Much of the visitor attitudes were reflective of prior work (Borun, 1977; Jarvis & Pell, 2002, 2005). Research by Jarvis and Pell focused on experiences of school groups to the Challenger Learning Center at the University of Leicester showed that positive experiences with science and space had small but statistically significant improvements in students' attitudes toward the subject matter. So, while science centers offer the potential to change visitor attitudes toward science, the change is small but significant. More frequently, visitors who come in with positive attitudes toward the content leave with those attitudes being reinforced (Falk & Adelman, 2003). Visitors whose attitudes were marginal benefited the most from the positive learning experiences. Visitors' attitudes toward learning were also strongly positive in the initial survey and generally remained so during the follow-up survey.

Some of the attitude factors correlated with demographic variables, such as level of education and household income (see Chapter 4: Correlations with Visitor Demographics). For instance, the attitude factor, Liking Learning, correlated significantly with level of education, household income, and gender. The correlations between the attitude factor Liking Learning and level of education and household income is expected, as individuals who enjoy learning typically seek out more opportunities to learn, including furthering their education in formal settings (Falk, 1998). In addition, higher education typically results in higher household incomes.

Staff Survey

Some of Science City staff's perceptions of the nature of science were not reflective of the expected description of science as a process for the generation of new knowledge. Staff perception more typically emphasized the strict adherence of scientists to the Scientific Method. Of the eight members surveyed, three accurately described the nature of science, two described science more loosely in terms of discovery and exploration, but the remaining three individuals indicated that they had no understanding of the nature of science. This is disturbing, as these individuals have contact with visitors to Science City. Having a lack of understanding of the nature of science limits their ability to act as a facilitator of discovery through inquiry.

Individuals who do not have a deep understanding of science as process cannot effectively help others learn about the process.

In contrast to research on informal learning, the majority of facilitators surveyed (five) felt that visitors should come away with specific content knowledge after interacting with the exhibit. Work done by Rennie and Williams (2002) at the Scitech Discovery Center reported that center staff stressed the idea that visitors should develop positive attitudes toward science from their visit and come to a broader relationship with science than simply viewing science as a wealth of facts to be learned. Both the education staff at Scitech Discovery Center (21%) and at Science City admits not having had much science education beyond school, though more at the Scitech Discovery Center (62%) had science at the university level. In conversations with some of the newer facilitators at Science City, many admitted to not having had a science course outside of those in high school. Differences in science education prior to employment at the science center may account for the different views of the goals of the science center. The staff's lack of a deeper understanding of science may influence their ability to help visitors interpret content during their (visitors') visit and thereby not gain a deeper understanding of the nature of science.

Behavioral Analysis

Comparisons between the visitor survey and behavior analysis are difficult to make due to demographic differences among the three samples (initial and follow-up survey, and behavior analysis). Comparisons of gender and race between the initial and follow-up visitor survey using a Chi-squared analysis found that the sample of visitors was statistically similar to the visitors of Union Station (Table 3.1). The same statistic found statistically significant differences among the same variables when the Union Station visitor population was compared to the behavioral analysis sample (Table 7.1). This suggests that comparisons made between the three groups may not be of practical significance due to the differences in populations. This also implies that the behaviors seen in the visitors who participated in the initial and follow-up survey may be different from the visitors tracked as part of the behavior analysis, thereby limiting the validity of the behavior analysis as a tool for validating the data collected in the initial and follow-up surveys.

Observations of visitors using the behavior rubric found that visitors, specifically children, frequently used not just the Shuttle Approach Simulator and Mars Rover as indicated in the initial and follow-up surveys, but also the Fitness Test (Figure 7.6). Adults manipulated the Robotic Arm most of any of the exhibits, while children were not seen interacting with this station. Together, adults and children frequently manipulated the Shuttle Approach Simulator, the Mars Rover, and the Dizziness Challenge. The appearance of three other stations frequently used by adults and children may be a reflection of the differences in the sample population between the visitor surveys and the visitors observed during the behavior analysis. It is doubtful visitors would choose to selectively omit interacting with one station over another to produce such a biased random error. Further research would be needed to determine if this error was due to the sample differences or indicative of some aspect of the Fitness Test, Robotic Arm, and Dizziness Challenge stations not being as memorable. It is possible that the use of video technology in the Shuttle Approach Simulator or the Mars Rover produced a higher level of novelty for the visitors, making the experience more memorable. The Robotic Arm, Fitness Test, and Dizziness Challenge do not incorporate these kinds of experiences. Instead, the tasks or the difficulty level at the three stations do not change. In contrast, the Shuttle Approach Simulator included three different landing simulators and the option to increase difficulty level. The Mars Rover station has obstacles, such as rocks, that can be moved about the exhibit area and left in new places by other visitors. The ability for the station to actively induce novelty with each interaction may increase visitor interest and thus memory of the exhibit station.

Summary

Visitors to the *Astronaut Training Center* at Science City frequently interacted with more complex stations, such as the Mars Rover and Shuttle Approach Simulator. The choice of these stations is thought to be due to the incorporation of immersion experiences through the use of built-in seating, video animation technology, and the ability of the stations to provide multiple interactive experiences within the single environment. The multiple interactive experiences also offer specific feedback from the exhibit to the visitor, which would result in the visitor changing his or her approach to the exhibit to conquer the challenge at hand. This approach to exhibit design can provide visitors with multiple new experiences at a given station. The complexity of the station also encouraged visitors to talk about their experiences with not only friends and family, but also with other visitors outside their group. These design criteria are incorporated in the design of three chemistry exhibits that link chemistry with everyday objects with which visitors are familiar discussed in the next chapter.

Chapter 9

Chemistry Exhibit Designs

Chemistry Exhibit Designs

The popularity of the Shuttle Approach Simulator has sparked interest in the potential of video-technology in informal learning environments for conveying positive, hands-on experiences with content not easily accessible through stationary exhibits. While this potential to spark learning exists, comparisons between visitors' perceptions of learning and observable behaviors have shown no statistically significant correlations in this study and in others (Borun et al., 1996; Dierking & Falk, 1994). Regardless, video-technology is a powerful tool to address concerns regarding the development of a chemistry exhibit, such as waste disposal, safety, and the cost associated with keeping the station stocked with reagents (Collard & McKee, 1998; Silberman et al., 2004; Templeton, 1992).

The use of video-technology would provide a cost effective way to reduce the amount of reagents used and waste produced, in addition to being a robust and visual method for conveying chemical concepts. A video interactive would allow visitors to work with the exhibit to construct a selection of chemical reactions and encourage further interaction to explore the reactions in depth. Videos or interactive computer games would also allow for some of the salient interactions described in previous chapters, such as pushing-buttons, manipulating a joy-stick, and immersing visitors in an authentic environment, to be built into the exhibit design

The following exhibit is designed to fit within the content already present at Science City. Specific links to content available at Science City are not made explicit, in order to maintain the flexibility of the exhibit, while at the same time allowing chemistry to be shown as the central science. The exhibit is intended to provide a context, in both the physical and personal sense as described by Falk and Dierking (2000) in Chapter 2, in which visitors can relate the subject matter. The focus of the exhibit is on green chemistry and chemical engineering due to the growing need to develop a knowledge base within the general public about the importance of chemical and energy efficiency through the design and implementation of new chemical processes.

Chemical Reactors: How Big is Our Chemical Footprint?

In keeping with the theme of Science City, an exhibit on how chemical reactors work to produce common household products, such as plastics, petroleum products, or cleaning solutions, could be used to show the impact of inefficient production on the environment. As visitors enter the exhibit, they can be immersed in a simulated production plant, with a test reactor, control room, and various pipes running materials throughout the area.

In the control room, visitors can interact with a display that controls a simulated reactor system. Variables such as amount of reactants, temperature, pressure, and volume could be changed within the control program. The program would allow visitors the option to vary either one or more of the variables during their interactions, with hints given to attempt to change only one at a time to find optimal conditions to run the reaction. Results of the changes can be reproduced both graphically and visually via changes within the physical reactor using color changes, noises, or movement. Potentially disastrous changes could be simulated through flashing warning lights, sirens, and movement within the exhibit as the reaction begins to run out-of-control. To try to circumvent visitors from having a reaction produce a disaster, prompts could be used to suggest visitors make other adjustments to the reaction conditions prior to an event occurring. Visitors who are able to simulate an optimal system could receive positive feedback from the reactor by watching it produce samples of the desired product. Intermediate levels of hazards could be addressed though the use of prompts advising the visitor that the reactor will be automatically shut down if changes to the conditions are not made or that less product will be produced as a result of current conditions. A supervisor figure within the program could be used to advise visitors of changes that could be made to the reaction to shift away from the hazardous conditions. Additional reactions could be examined in this way, allowing the exhibit the ability to change without large costs in renovation.

For example, visitors could be prompted to help with the optimization of the production of ammonia for a fertilizer plant using the Haber process. Visitors would be given the starting materials, water, a carbon source, and nitrogen and be asked to develop an optimal method for producing ammonia gas. As part of their chemical stock room shelf, visitors could be prompted to use the Haber process of reacting the water and carbon together to form carbon monoxide and hydrogen gas (Scheme 9.1). Visitors could adjust the pressure, volume, temperature, or add a catalyst to determine how those changes would maximize the amount of products produced. Prompts could

Scheme 9.1: Haber Synthesis of Ammonia

$$H_2O_{(g)} + C_{(s)} \longrightarrow CO_{(g)} + H_{2(g)}$$

$$N_{2(g)} + 3H_2 \longrightarrow 2NH_{3(g)}$$

be used to remind visitors that the output of hydrogen gas would be used in the next step to form the desired product, ammonia. Once the first step was optimized to the visitor's satisfaction, they could proceed to the second step, where they would cause the hydrogen gas they produced in the first step to react with the nitrogen available on the stock room shelf. Again, the same variables could be used to help visitors optimize the product yield, with the goal of finding the right conditions to produce the largest amount of ammonia given the amount of starting material they began with. Additional reactions could be used to show how carbon monoxide is converted to carbon dioxide and further used in other side processes to prevent substantial release of the green house gas. The process of using a by-product for other chemical reactions could be explored further both within the exhibit and as part of an interactive website available to visitors outside of the science museum.

At each step, during the reaction, visitors can be shown animations of the reaction occurring both on the macroscopic level and the microscopic level through the use of a fictitious "high-powered microscope." Visitors can be prompted to zoom in on the reaction and watch it in process in this manner. This microscope may lead some visitors to come away with the idea that scientists can physically see reactions occurring as they do within the exhibit. Research on the scientific misconceptions visitors come away with from an exhibit have not been examined in the literature on learning in science museums.

This exhibit could be made into a competition where visitors are encouraged to produce the most amount of product for a given amount of starting material. A Tops Producers screen, similar to “top scores” list on common video games, could show the yield for the twenty top individuals with the most product. This would provide visitors with an incentive to optimize the conditions for their reaction. Besides product yield, a top scores list could also show individuals who were able to optimize their reaction to use the least amount of reagents for a desired amount of product, or to have used the least amount of energy for the reaction to occur.

In addition to a simulated chemical reactor, visitors would also be able to interact with a second simulator that allows them to explore the effects of chemical processes on the environment. This could allow visitors to explore the twelve principles of green chemistry as originally described by Anastas and Warner (1998) through having the simulation include or not include methods incorporated into the principles (Table 9.1). This reactor could potentially simulate two separate chemical reactions, where the visitor is asked to compare a hazardous chemical reaction with one that is green in nature. Visitors could be asked to view shortened material safety data sheets (MSDS) to determine some of the safety issues associated with using specific chemicals. This can be conveyed using a series of symbols next to the hazards to help visitors weigh the potential risk. A comparison with the MSDS for water could also be useful in this respect. Other potential variables to change could

Table 9.1: The Twelve Principles of Green Chemistry

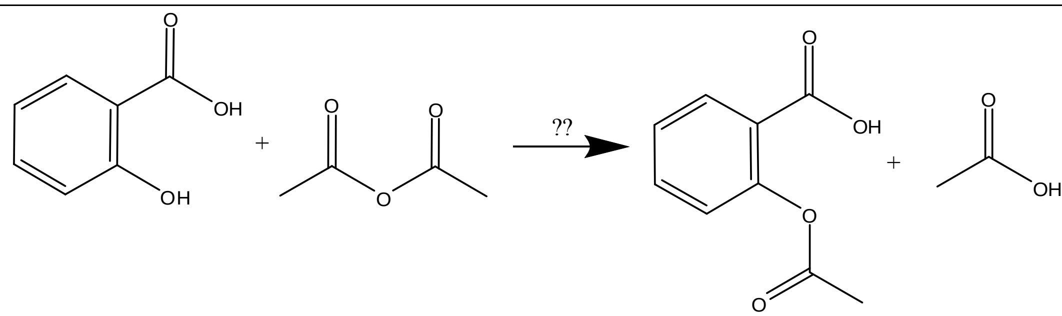
1. Prevent waste.
2. Design safer chemicals and products.
3. Design less hazardous chemical syntheses.
4. Use renewable feedstocks.
5. Use catalysts, not stoichiometric reagents.
6. Avoid chemical derivatives.
7. Maximize atom economy.
8. Use safer solvents and reaction conditions.
9. Increase energy efficiency.
10. Design chemicals and products to degrade after use.
11. Analyze in real time to prevent pollution.
12. Minimize the potential for accidents.

From Anastas, P., & Warner, J. (Eds.). (1998). *Green Chemistry: Theory and Practice*. New York: Oxford University Press.

again be temperature, pressure, volume, and the relative amounts of the reactants to improve the efficiency of the reaction to address the principles of using safer solvents and reaction conditions, using catalysts, and potentially avoiding chemical side-products. The effects of altering the variables can be shown graphically and pictorially via amounts of reactants and products being trucked into the chemical plant on the macroscopic level or by using the powerful microscope able to view reactions on the microscopic level. Comparisons may be made between two sample reactions, one that employs green chemistry methods and one which does not, and asks visitors to determine which method was the best based on examining the twelve principles and how they relate to the sample reactions.

For example, visitors could explore the synthesis of aspirin using methods adapted from Montes, Sanabria, Garcia, Castro and Fajardo (2006). Aspirin provides an example of a product whose importance would be obvious to the casual visitor. Within the computer simulation, visitors can mix together salicylic acid and acetic anhydride to determine if the reaction will form aspirin (acetylsalicylic acid) (Scheme 9.2). Visitors could be prompted to change the amount of reagents being added, increase the temperature, or add a catalyst to see if that has an effect on production

Scheme 9.2: Synthesis of Aspirin



?? could be H_2SO_4, H_3PO_4, $AlCl_3$, $MgBr_2 \cdot OEt_2$, $CaCO_3$, NaOAc, Et_3N, DMAP, or no catalyst present.

.Visitors may also be given the option to use different heat sources, such as an open flame, a more encompassing heating mantle, or a microwave oven on varied heating levels. These changes would address six of the green chemistry principles: prevent waste, design less hazardous chemical syntheses, use catalysts instead of stoichiometric reagents, maximize atom economy, use safer solvents and reaction conditions, and increase energy efficiency. If visitors choose to add more reagents, they could be prompted that adding more reagents may not have an effect on overall output if no reaction is occurring, thereby causing an increase in the amount of waste. Use of excessive heating would cause a prompt to come up that indicates that they were not using energy efficiently. After determining the outcome of the initial reaction, they can opt to explore how adding different catalysts can cause the reaction to proceed.

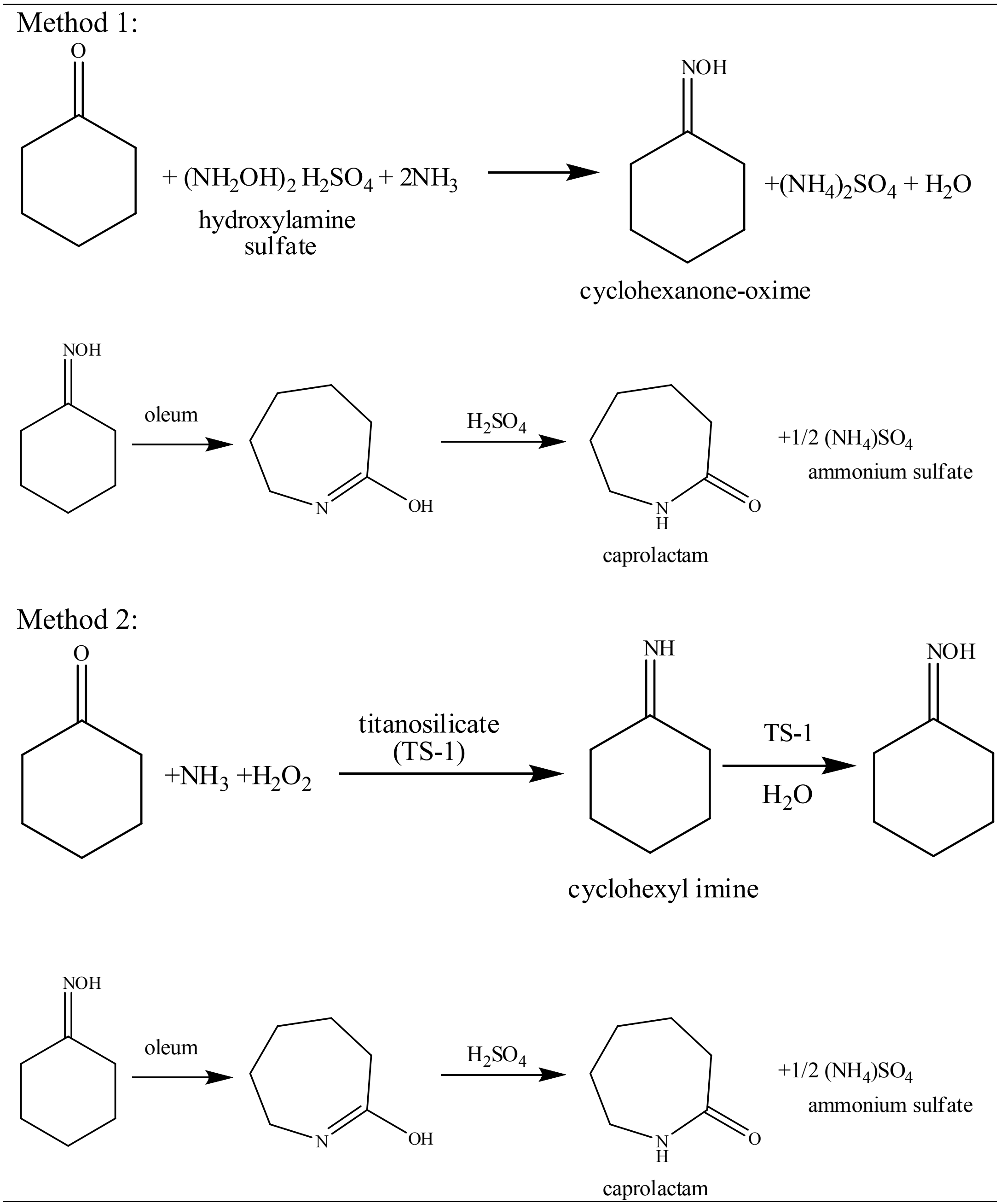
The station should encourage visitors to discuss with each other which process would be the least hazardous and most efficient to emphasize the learning potential associated with socio-cultural constructivist interactions. Positive outcomes can be reinforced by showing citizens of the city using the products produced safely and the environment looking green and healthy. While negative outcomes resulting in large fish kills or species becoming extinct is rare, these are outcomes of which the general public is aware. The goal of the exhibit is to help guide the visitor in seeing that these are not desired outcomes of the chemical industry and many methods are employed to reduce the potential for disaster through using side-products, reducing the amount of reagents used, and being mindful of how chemicals are being disposed.

A second example of a reaction that visitors could use to explore green chemistry is related to the formation of nylon-6. Two methods are commonly used to produce ε-caprolactam, the precursor to nylon-6 (Scheme 9.3). Both methods start with cyclohexanone and through multiple steps produce cyclohexanone-oxime, which is then converted to caprolactam. Visitors could explore these two methods, by examining the efficiency at which they convert to products, both measured in terms of atom economy and product yield. Once having found optimal conditions within these two reactions, visitors can be introduced to an alternative approach, as described by Thomas and Raja (2005) (Scheme 9.4).

Again, the format of a competitive game can be used within the simulation. Visitors would be prompted to find the ideal conditions for the reaction to produce ε-caprolactam. The reactants could be given as part of a stock room shelf or as a pre-defined method, depending on the level of the visitor. Visitors would drag and drop reactants into a simulated beaker and tell the reaction to start. The reaction could be viewed both on the macroscale level and the microscale level using a "high-powered microscope" built into the simulation. Visitors may also be given an option to run all three reactions at the same time to compare the results. Facilitators could be incorporated to suggest potential ways for adjusting variables and encouraging visitors to discuss how the changes affect the outcome of the reaction.

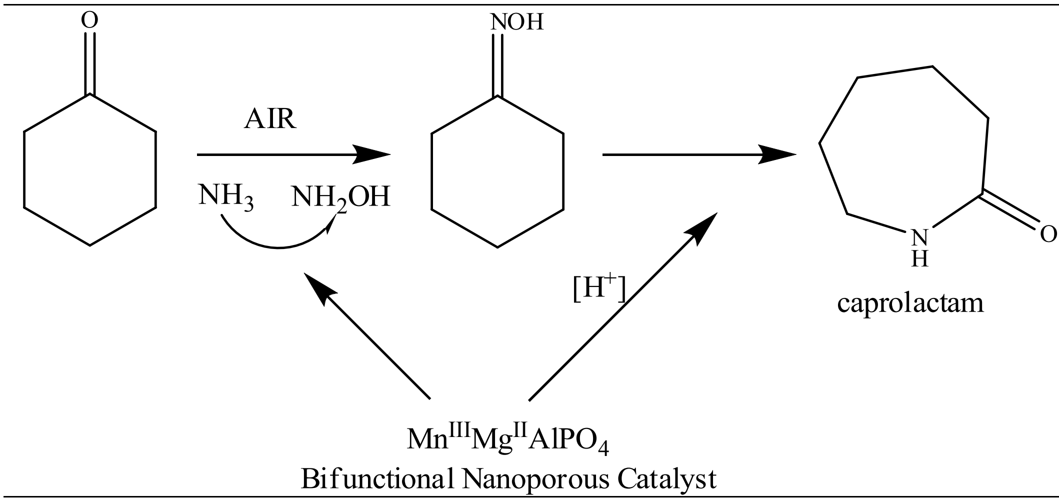
This series of reactions offers a number of green outcomes to explore. First is the inefficient atom economy of the first two reactions, where multiple steps are needed to produce the lactam. Secondly, for both of the two common reactions, ammonium sulfate is produced as a by-product as a result of the Beckmann rearrangement used to produce the caprolactam in the second step. High production of the low-value by-product would result in the visitor losing points on their overall reaction score for production of a low-value waste product. Visitors would also receive reduced scores for their use of the reagents in the first two reactions, hydroxylamine sulfate and ammonia in Method 1 and aqueous hydrogen peroxide in conjunction with titanosilicate TS-1, a solid redox catalyst. Optimally, visitors would

Scheme 9.3: Two Common Reactions for the Production of ε-Caprolactam (Precursor of Nylon-6)



From Thomas, J. M., & Raja, R. (2005). Design of a "green" one-step catalytic production of ε-caprolactam (precursor of nylon-6). *Proceedings of the National Academy of Sciences of the United States of America, 102*(39), 13732-13736.

Scheme 9.4: Production of Caprolactam Using Solid Catalysts



From Thomas, J. M., & Raja, R. (2005). Design of a "green" one-step catalytic production of ε-caprolactam (precursor of nylon-6). *Proceedings of the National Academy of Sciences of the United States of America, 102*(39), 13732-13736.

want to use the one-step formation of caprolactam using $Mn^{III}Mg^{II}AlPO_4$ as a catalyst. This reaction can be run without solvents, in air, and without the production of the unwanted ammonium sulfate as a by-product. This reaction is much more efficient in terms of atom economy, production of waste, use of solvents, use of catalysts, and use of less hazardous reagents, all of which would earn the visitor points within the system.

Summary

This chapter presented the exhibit, *Chemical Reactors: How Big is Our Chemical Footprint?* This exhibit looks at what the chemical industry is doing to protect the environment through the green chemistry principles identified by Anastas and Warner (Anastas & Warner, 1998). By incorporating video interactive technology, visitors have the opportunity to explore chemical reactions farther in depth than they would using traditional wet methods. Exhibits are designed to encourage visitors to interact with each other and the exhibit using inquiry-based methods as they attempt to produce chemically and energetically efficient reactions that yield products with which they are familiar. In the next chapter, a summary of the conclusions made is presented, the state of inquiry at Science City will be examined and recommendations for further research will be presented.

Chapter 10

Summary and Conclusions

Summary

This research was developed out of a love of helping the public better understand science, particularly chemistry as a discipline. Science centers in particular have done little in the way of developing permanent chemistry exhibits that portray the discipline as active and associated with the other scientific disciples (Templeton, 1992). The blame for this problem has frequently been placed on the perception of a need for wet chemistry experiments, where reagents are caused to react in bulk quantities and disposed of after one use or the lack of interaction between professional chemists and science museum or center professionals. Further still, is the lack of research in the literature in regard to successful chemistry exhibits within science museums, to help guide the development of new and innovative programs.

Being limited by commuting distance and the lack of a popular chemistry exhibit, the *Astronaut Training Center* at Science City was selected as a model of a successful exhibit for study, in terms of visitor enthusiasm for the content and number of visitors each day through the exhibit. This study set out to identify how visitors perceive learning in a science center and if manipulating interactive exhibits had an effect on visitor learning or their attitudes toward the scientific content. Specifically, the following questions were addressed: (1) Do visitors recognize they are learning from their interactions with the exhibit? and (2) If so, what do they think they are learning?

This study identified seven behavior factors that group aspects of the exhibit, such as talking about the exhibit content, use of the video game technology, and exhibits that include push-buttons and eye-hand coordination skills. These behaviors were found to not correlate with visitor learning but do play a role in developing positive attitudes toward experiences at the science center and with science. Correlations were present within the interaction factors, indicating that aspects of the exhibit may produce the behaviors that have previously been shown to be associated with visitor learning, such as constructing new knowledge by linking it with previous knowledge and experiences. Interaction factors, such as Video Game Stations, Push-Button Stations, and the specific station Astronaut Fitness Test, correlated significantly with Communication. This suggests that when visitors perform these tasks, they are more likely to talk about their experiences with other visitors, a behavior strongly associated with the construction and reconstruction of knowledge.

Not only has talking about the exhibit content been linked with visitor behavior, but also visitors reading the signs within the exhibit. Visitors who read the signage reported having felt the signs were helpful in answering their questions and were more likely to do what the signs suggested. As visitors were more likely to perform the behaviors suggested, signage in future exhibits should be designed to incorporate guided inquiry-based learning principles to encourage visitors to explore the exhibit. The signs may be able to limit some of the wide outcomes seen in research in this area.

Research on learning in public venues is challenging due to the flexible and frequently non-controllable, in a scientific sense, environment. Choice plays a major role in visitor interactions, from choosing to visit the science center down to which stations to interact with and for how long. This role of choice makes testing for content knowledge gains difficult. One visitor may choose to interact with one station but skip over another. They may or may not read the signage associated with the station, making content knowledge tests inappropriate. Testing these individual's content knowledge may incorrectly conclude that visitors did not learn from their visit or over estimated the knowledge gained from the visit and its usefulness to the visitor. An interactive survey may be needed to explore content knowledge such that it adjusts questions based on input by the visitor as to which exhibits they interacted with.

Based on visitor interactions with specific exhibit stations, visitors to the *Astronaut Training Center* learned about how to land a space shuttle through interacting with the Shuttle Approach Simulator. They also frequently manipulated the Mars Rover to gain experiences moving an object via a remote system. While these outcomes may not be content oriented, they did provide valuable positive experiences with science and may encourage some visitors to seek out other areas of science to learn about. Even though many of the visitors were unable to pinpoint specific science knowledge gained or express it in a manner consistent with the accepted scientific view, general outcomes such as the ones described can be as valuable or more valuable for increasing the public's understanding of science. By engaging the public through positive experiences with science they may be more likely to seek out other, more formal methods of learning about science in general and chemistry specifically. By using informal learning environments, such as those offered by science centers, the fear of chemistry can be reduced by providing experiences that are contrary to what visitors expect from the subject matter. The exhibit designs suggested in the previous chapter attempt to enlighten the public as to some of the ways chemistry positively influences their lives.

One of the methods suggested for incorporating chemistry into the science center is the use of video technology. This technology will allow for the reduction of risk to the visitor and waste materials produced after reactions were completed. Video technology is more robust in nature in comparison to the need to refill chemicals on a daily or weekly basis in the exhibit and facilitators will be free to interact with visitors throughout the exhibit instead of standing guard over a potentially hazardous exhibit.

Visitor's attitudes toward space and science were also examined. Generally, visitors to the *Astronaut Training Center* held positive attitudes toward learning about science in informal environments, such as Science City, and toward the space science content presented within the exhibit. These attitudes focused around their enjoyment of learning and their ability to seek out opportunities to learn. The attitudes were most typically held by individuals with higher levels of education and household income. The attitudes remained constant from the initial to the follow-up visitor survey administered a few months after the initial survey.

The survey of Science City facilitators showed that they did not have a complete understanding of the nature of science. This result was rather shocking, as they are on the frontline in helping the public understand not only science, but the nature of science as well. Facilitators at other science museums examined have shown better understandings of the nature of science as well as the purpose of science centers (Falk & Adelman, 2003). While more facilitators at the center studied by Falk and Adelman indicated having studied science at the university level than those seen at Science City, a sizable portion had only had science at the high school level. Training of the facilitators in the goal of the science center and desired learning outcomes in visitors may play a larger role in the outcomes seen. Positive learning outcomes in visitors can be influenced by the knowledge of the facilitators visitors come in contact with during their visit.

State of Inquiry at Science City

Throughout this study, the underlying assumption has been that the *Astronaut Training Center* is a prime example of an inquiry-based exhibit. It is not. The *Astronaut Training Center* is an example of a more popular exhibit within Science City and that offers a variety of ways to interact with content relating to the lives of astronauts in space. The more popular stations, the Shuttle Approach Simulator and the Mars Rover, provide immersion interactions in a setting that is far more detailed than other exhibits found throughout the center, with the exception of the area designated for programming as part of the Challenger Learning Center's simulated astronaut missions. This area is not included in the general admission cost to visit Science City, but is reserved for school groups of 15 or more.

While having come in contact and exploring an exhibit has been shown to develop enthusiasm toward particular subject matter (Adelman et al., 2000), it is not the same as inquiry. Exploration is typically done on a surface level, inquiry prompts individuals to dig deeper to find meanings for new experiences. Visitors should be prompted to investigate a phenomenon, analyze the outcomes of the investigations, and draw conclusions based on what they completed. This may not be possible in an environment where visitors typically spend less than thirty seconds at a station. For science museums to do true inquiry, they would need to develop exhibits that encourage questioning and communication among visitors and have multiple outcomes to present visitors with an accurate representation of the process of scientific inquiry.

Most exhibits within the science center are like the Crime Lab, limited in the number of enriching experiences and interactions with the underlying pure science of the technology surrounding us in our daily lives. Science is without a doubt all around us in the modern world, stretching from the within our houses, to the utilities that bring us electricity, clean water, and cable television. But Science City is a misnomer, as it only presents the technology behind modern cities. Most large cities also offer television stations with in-house meteorologists and storm centers to track the changing weather conditions found in the Midwest. Little of the underlying science of how television stations broadcast information around the globe is discussed. No mention is made of the technology needed to transmit information between weather spotters back to the television station or the science used to track storms via Doppler radar and the NEXRAD network. Another example typical of the Midwest is a farming community, where again science has played a role in developing crops that are more drought tolerant than previous varieties, but only the video experience in this area is of driving a tractor through a corn field.

Science City's motto of "let curiosity be your guide" falls short as well, as many exhibits offer only one, pre-defined outcome per exhibit station. What inquiry is not is a pre-defined, single out-come experience. Scientific inquiry is framed by not knowing the solution and is instead the process of finding the answer. Yes, this is a frustrating experience for visitors, students and adults, who are trained to find the correct response, knowing full well the teacher has the answer and many students before them have performed the exact same tasks. Science City does not offer a curiosity driven experience, instead it provides a leisurely stroll through the technology running behind-the-scenes in a city.

All should not be considered lost with this science center. The idea of linking the familiar environment of a major city with the science used to bring it to its grandeur deserves applause. The public needs to experience science as part of their natural world before being driven by curiosity to further explore the natural world using the scientific lens. Exhibits within the center have the potential of being developed further to meet the expectations the name implies. The Crime Lab, for instance, generally consists of five sparse stations, where visitors can view five static crime samples at each station. This exhibit could be redesigned such that visitors could interact with more modern methods of determining a culprit. Visitors could be given the opportunity to purchase a cheap radio or infrared tags that are connected to an in-house network. This network would allow visitors to interact with exhibit stations based on a series of randomly selected outcomes, in a similar manner as the current case folder system. Instead of picking up a folder with lots of reading related to the case visitors are asked to solve, they can swipe their tag next to a sensor at a station and interact with video prompts that outline the crime scene and potential suspects.

Both the crime scene and the suspects could be selected from a poll of potential individuals whose data was stored in the network behind-the-scenes. Current stations, such as the finger print analysis, sketch artist, and hair samples analysis could be updated to detect the tag and display results relating to those individuals and the crime. Additional stations, like one for a blood sample analysis could be created for visitors to make comparisons between a crime scene sample and ones from the potential suspect. If adults wanted a more complex interaction, advance crime scenes could be created where multiple individuals have various qualities that overlap within the investigation, like the same hair color, similar facial structures, or blood types. Adults could be prompted to look for other methods within the stations to find more information through an iterative process.

Facilitators could also play a role in this station, acting as another detective willing to help visitors sort through the clues in the visitor’s case. By taking on an active facilitation role, facilitators can prompt visitors to think about how they are attempting to solve the crime. Visitors could be prompted to use the information gained from the hair sample analysis to eliminate potential suspects, or how DNA analysis can be used to identify the killer. Facilitators would also need to be better trained in guiding visitors through an inquiry process. Without a good understanding of the inquiry process, many facilitators may find it difficult to guide visitors through the exhibit in this manner. Improper training may lead to the facilitator solving the problem for the visitor, instead of allowing the visitor to explore with limited guidance.

Future Work

Much work is still needed to understand learning about chemistry within informal environments. While this study did not directly address chemistry, it is meant to act as a gateway for further study. This study was intended to identify aspects of the *Astronaut Training Center* that made the exhibit and the stations within the exhibit popular among visitors. By harnessing some of these features, the potential of developing an effective chemistry exhibit should be increased. The ideas put forth in this study for the development of a future chemistry exhibit are based in the results of this work and concerns posed by employees at Science City.

Preparation of the science center's facilitators will be of utmost importance. The coverage of chemistry in high school may not be adequate for facilitators to develop positive attitudes toward a new chemistry-themed exhibit and come away with a better appreciation for the role modern chemistry plays in society. As chemistry often suffers from a “I-hated-it-in-high-school” syndrome, the facilitator’s attitudes can go a long way to instill the role chemistry plays as being more than polluting the environment and causing explosions.

As part of the evaluation of a future chemistry exhibit, visitor surveys should be kept short and focus on visitors’ understanding and attitudes toward chemistry and science in general. Splitting the single survey used here into two surveys, one on visitors’ understanding and one on their attitudes toward chemistry may help in this respect. The reliability and factor analysis presented in this work will be able to guide the development of a second survey for use either with a new chemistry exhibit or with further evaluation of the *Astronaut Training Center*. Refinements to the current survey can be made to ensure that questions associated with the identified factors allow for ease in interpretation. Chemists should not expect the public’s understanding of chemistry to reach the same level as their own. Chemists need to examine their discipline and identify key areas on which to focus their efforts when helping the public become more chemically literate.

A newer survey of science centers across the U.S. is needed to identify specific areas of chemistry already addressed with existing facilities. No study has addressed how chemistry is presented within other exhibits such as those with biology and physics focuses. Opportunities exist within these exhibits to help visitors link the vital function of chemistry to subjects they find more interesting, such as biology and physics. New exhibits like the three suggested in this thesis can also work to build these connections, as well as emphasize positive attitudes toward chemistry. By developing these connections, the public can begin to see chemistry as a beneficial science and not one to be feared.

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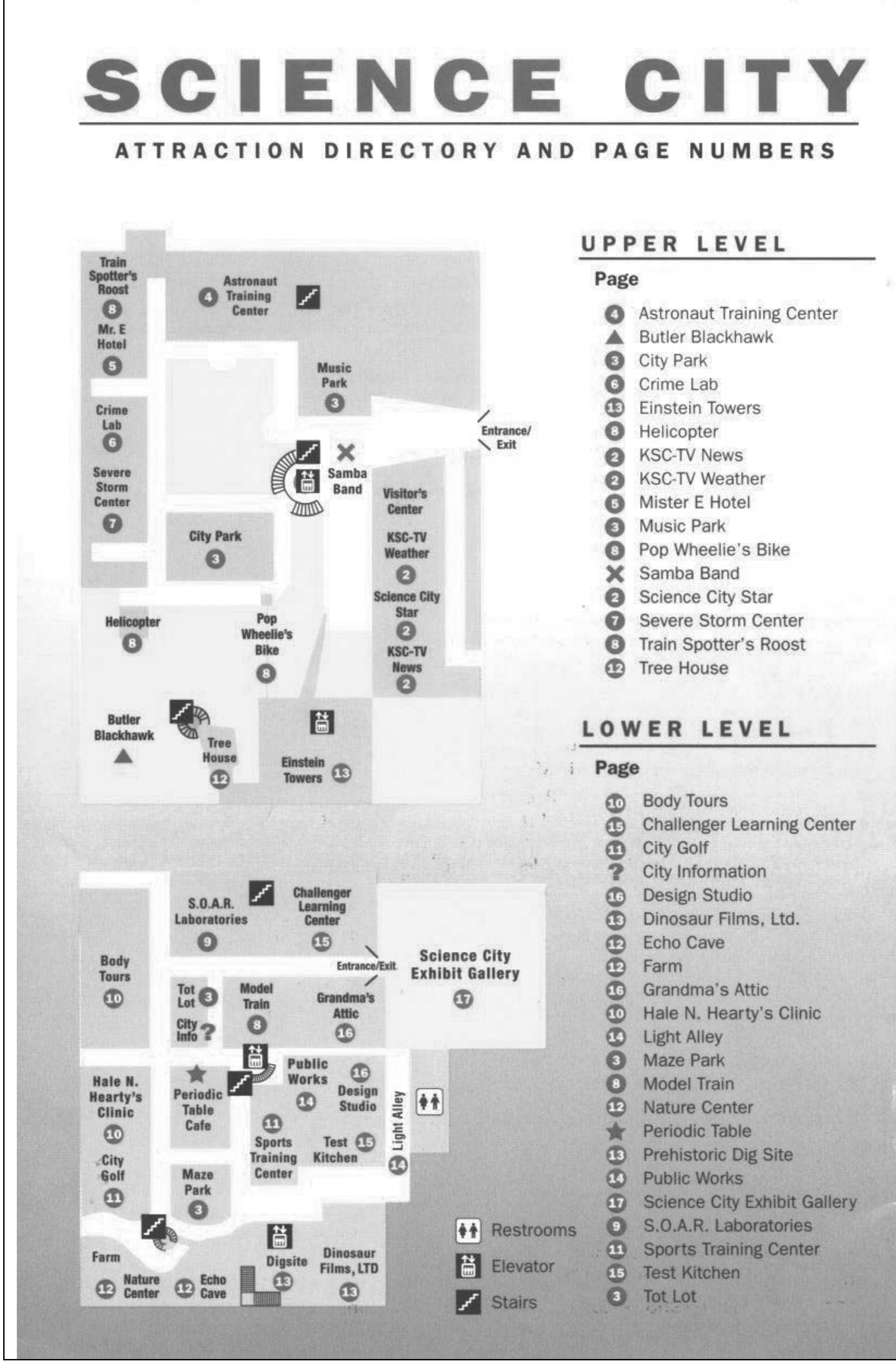
Appendix

Appendix I: Layout of Science City



Map of Science City

Appendix II: Surveys

Date: ________________ Time started: __________ am / pm
Interview #: ____________ Time ended: __________ am / pm

Science City Astronaut Training Center Survey

For the purpose of this survey, the term exhibit refers to the Astronaut Training Center exhibit area, which includes the Mars exhibit, space shuttle simulator, and astronaut living quarters.

Section I: Astronaut Training Center Exhibit

A. Interaction:

Please indicate your level of interaction with the exhibit. The value (1) corresponds to feeling that you did not interact with the exhibit in the specified manner. A value of (3) indicates that you feel you interacted with the exhibit some and (5) that you interacted a lot.

1. Please circle how much you:

	Not at all		Some		A lot
a. manipulated the:					
shuttle approach simulator	1	2	3	4	5
Mars rover	1	2	3	4	5
Mars soil test	1	2	3	4	5
"compatibility test" to center the Earth on the screen	1	2	3	4	5
robotic arm	1	2	3	4	5
Astronaut fitness test	1	2	3	4	5
"emergency repairs" knobs	1	2	3	4	5
b. talked about the exhibit:	1	2	3	4	5
with the people in your group or family.	1	2	3	4	5
with other visitors.	1	2	3	4	5
with Science City facilitators.	1	2	3	4	5
c. guided someone through the exhibit.	1	2	3	4	5
d. read signage next to the stations.	1	2	3	4	5

2. Did you:

	Not at all		Some		A lot
a. use the shuttle approach simulator	1	2	3	4	5
b. drive the Mars Rover	1	2	3	4	5
c. examine the Mars soil test	1	2	3	4	5
d. work with someone else to "center Earth" on the "compatibility test"	1	2	3	4	5
e. examine the Earth Monitor	1	2	3	4	5
f. drive the robotic arm	1	2	3	4	5
g. take the astronaut fitness test	1	2	3	4	5
h. examine the satellite orbit simulator	1	2	3	4	5
i. make "emergency repairs" on the shuttle	1	2	3	4	5
j. take the dizziness challenge	1	2	3	4	5
k. read explanatory labels	1	2	3	4	5

3. Did you read the signs next to the stations? yes no

a. If you answered yes:

Did you do what the signs said? yes no

Did you find the signs helpful when playing with the exhibit? yes no

Did the signs answer your questions about this exhibit? yes no

b. If you answered no:

Would you like a resource that helps you find out more information? yes no

If so, what kind of resource would you find helpful?

a. booklet   c. signs

b. internet website   d. other, please specify: ____________________

B. Visitor Attitude:

Please indicate your level of agreement with the following statements. A response of (1) indicates that you mostly disagree with the statement, (3) you are indifferent or neutral, and (5) you mostly agree.

4. Please indicate level of agreement:

	Mostly disagree		Neutral		Mostly agree
a. I feel the exhibit added to my understanding of an astronaut's experiences.	1	2	3	4	5
b. I wasn't able to handle or manipulate much in the exhibit.	1	2	3	4	5
c. I find space travel interesting.	1	2	3	4	5
d. I didn't like reading all of the labels.	1	2	3	4	5
e. I learned something about Mars.	1	2	3	4	5
f. Remotely operating the rover isn't as exciting as seeing the rover move.	1	2	3	4	5
g. Life on Mars is similar to life on Earth.	1	2	3	4	5
h. The "Living Quarters" exhibit reflected my expectations of life on a space shuttle.	1	2	3	4	5
i. I feel the Living Quarters exhibit could be more detailed.	1	2	3	4	5
j. Life in a space shuttle is different from life on Earth.	1	2	3	4	5

5. Based on your experience, please indicate your level of agreement.

		Mostly disagree		Neutral		Mostly agree
a.	I found the exhibit enjoyable.	1	2	3	4	5
b.	I don't like science.	1	2	3	4	5
c.	I feel the people I was with enjoyed the exhibit.	1	2	3	4	5
d.	I enjoyed interacting with the exhibit and my group.	1	2	3	4	5
e.	I want to learn more about astronauts.	1	2	3	4	5
f	I like watching educational science television.	1	2	3	4	5
g.	I don't like to read about science in a newspaper.	1	2	3	4	5
h.	Scientific knowledge is based in absolute truth.	1	2	3	4	5
i.	Before my visit, I feel I had a weak knowledge about space exploration.	1	2	3	4	5
j.	I found enough to do in this exhibit.	1	2	3	4	5
k.	Talking with a facilitator is helpful.	1	2	3	4	5
l.	The signs helped me understand the exhibit better.	1	2	3	4	5
m.	I did not find the exhibit challenging.	1	2	3	4	5
n.	I need more information to understand the exhibit.	1	2	3	4	5
o.	I like learning.	1	2	3	4	5

6. Did you enjoy this exhibit? yes no

7. Do you feel you learned anything from the exhibit? yes no

If so, please describe:

8. What do you think the exhibit is trying to show?

9. What comes to mind when you think about this exhibit?

Section II: Visitor Demographics:

To allow for comparison among groups of people, we'd like to have some information about the individuals who completed the survey. All responses are confidential and you will not be personally identifiable in any future publications regarding the collected information. Please indicate your response in the matter suggested.

10. What prompted your visit to Science City today? (circle one)

a. Brought out-of-town company

b. Are out-of-town company.

c. Wanted to do something educational with children.

d. Wanted to see Science City.

e. Recommended by a friend.

f. Read about Science City in a newspaper, magazine, or tour guide.

g. Heard a TV or radio ad.

h. Other, please specify: ____________________

11. Have you visited Science City before? yes no

If so, not counting this visit, how many times in the past year have you visited?

0 1 - 2 3 - 4 5 +

12. How many people are you with today?

0 1 - 2 3 - 4 5 - 6 7 +

13. Would you describe the people you are with as (circle one):

Family Friends Co-workers Schoolmates or students

14. Did you come with at least one child below the age of 18? yes no

If you answered yes,

a. How many children did you come with?

0 1 - 2 3 - 4 5 - 6 7 +

b. What is/are their ages? (circle all that apply)

<1 to 2 3 - 5 6 - 8 9 - 11 12 - 14 15 - 17 1 8 +

15. Which category best describes the highest level of education you have completed (circle one):

a. Elementary
b. High school
c. Some college
d. Undergraduate degree
e. Advanced degree

16. If you have a college degree, what was your major? (circle one)

a. Fine/Performing Arts
b. Science and Engineering
c. Medical related
d. Education
e. Journalism
f. Liberal Arts
g. Not sure
h. No college experience

17. Please circle the category that includes your annual HOUSEHOLD income:

a. Less than $15,000
b. $15,000 - $29,999
c. $30,000 - $49,999
d. $50,000 - $74,999
e. over $75,000

18. Ethnicity:

a. Caucasian
b. African-American
c. Asian
d. Hispanic
e. Other, specify: ______________________

19. Gender: Male Female

20. As part of a follow-up study on learning at Science City, would you be willing to have a researcher contact you in three to six months to ask some follow-up questions?

yes no

If yes, how may we contact you?

Name: ______________________

Phone: ______________________

Email: ______________________

Mail: ______________________

Date: ________________ Last 4 digits of home phone: ___________

Science City Astronaut Training Center Follow-Up Questionnaire

For the purpose of this survey, the term exhibit refers to the Astronaut Training Center exhibit area, which includes the Mars exhibit, space shuttle simulator, and astronaut living quarters. The CEBC, funded in part by the National Science Foundation, appreciates your answers to the following questions. All responses will be strictly confidential.

Your participation is voluntary and your assistance will help us improve the program. Your time to complete this survey is appreciated. If you have any questions, please contact April French at aprilf@ku.edu

A. Interaction:

Please indicate your level of interaction with the exhibit. The value (1) corresponds to feeling that you did not interact with the exhibit in the specified manner. A value of (3) indicates that you feel you interacted with the exhibit some and (5) that you interacted a lot.

Please circle how much you:

	Not at all		Some		A lot
1. guided someone through the exhibit.	1	2	3	4	5
2. read signage next to the stations.	1	2	3	4	5
manipulated the:					
3. shuttle approach simulator	1	2	3	4	5
4. Mars rover	1	2	3	4	5
5. Mars soil test	1	2	3	4	5
6. "compatibility test" to center the Earth on the screen	1	2	3	4	5
7. robotic arm	1	2	3	4	5
8. Astronaut fitness test	1	2	3	4	5
9. "emergency repairs" knobs	1	2	3	4	5
talked about the exhibit:					
10. with the people in your group or family.	1	2	3	4	5
11. with other visitors.	1	2	3	4	5
12. with Science City facilitators.	1	2	3	4	5

B. Visitor Attitude:

Please indicate your level of agreement with the following statements. A response of (1) indicates that you mostly disagree with the statement, (3) you are indifferent or neutral, and (5) you mostly agree.

Based on your experience, please indicate your level of agreement.

	Mostly disagree		Neutral		Mostly agree
13. I found the exhibit enjoyable.	1	2	3	4	5
14. I feel the people I was with enjoyed the exhibit.	1	2	3	4	5
15. I enjoyed interacting with the exhibit and my group.	1	2	3	4	5
16. I want to learn more about astronauts.	1	2	3	4	5
17. Before my visit, I feel I had a weak knowledge about space exploration.	1	2	3	4	5
18. I found enough to do in this exhibit.	1	2	3	4	5
19. Talking with a facilitator is helpful.	1	2	3	4	5
20. The signs helped me understand the exhibit better.	1	2	3	4	5
21. Computer technology is a valuable learning tool.	1	2	3	4	5
22. I find the exhibit challenging.	1	2	3	4	5
23. Computer simulations help me feel more like an astronaut.	1	2	3	4	5
24. I feel that I have a better understanding of what an astronaut does.	1	2	3	4	5
25. Video games are teaching tools.	1	2	3	4	5
26. I learned something from this exhibit.	1	2	3	4	5

27. Describe what you feel you learned from the exhibit.

____

____

____

28. What do you remember most about your visit to the Astronaut Training Center?

____

____

____

29. What would make this exhibit more meaningful to you?

____

____

30. Please estimate the amount of time it took you to complete this survey.

1 – 5 minutes   5 – 10 minutes   11 – 15 minutes   15 + minutes

Date: ________________ Time started: __________ am / pm
Interview #: ___________ Time ended: __________ am / pm

Astronaut Training Center Staff Survey

For the purpose of this survey, the term exhibit refers to the Astronaut Training Center exhibit area, which includes the Mars exhibit, space shuttle simulator, and astronaut living quarters.

Section I: Astronaut Training Center Exhibit

A. Interaction:

Please indicate your perception of the level of visitor interaction with the exhibit. The value (1) corresponds to feeling that visitors do not interact with the exhibit in the specified manner. A value of (3) indicates that you feel visitors interact with the exhibit some and (5) that visitors interact a lot.

1. Do you feel visitors:

	Not at all		Some		A lot
a. manipulate the:					
shuttle approach simulator	1	2	3	4	5
Mars rover	1	2	3	4	5
Mars soil test	1	2	3	4	5
"compatibility test" to center the Earth on the screen	1	2	3	4	5
robotic arm	1	2	3	4	5
Astronaut fitness test	1	2	3	4	5
"emergency repairs" knobs	1	2	3	4	5
b. talked about the exhibit:					
with the people in their group or family.	1	2	3	4	5
with other visitors.	1	2	3	4	5
c. guided someone through the exhibit.	1	2	3	4	5

2. Do visitors read the signs next to the stations?	yes	no
a. If you answered yes:		
Do they do what the signs say?	yes	no
Do you think the signs are helpful when playing with the exhibit?	yes	no
Did the signs answer your questions about this exhibit?	yes	no

B. Staff Attitude:

Please indicate your level of agreement with the following statements. A response of (1) indicates that you mostly disagree with the statement, (3) you are indifferent or neutral, and (5) you mostly agree.

3. Please indicate your level of agreement:

	Mostly disagree		Neutral		Mostly agree
a. I feel the exhibit adds to visitors' understanding of an astronaut's experiences.	1	2	3	4	5
b. Visitors are able to handle or manipulate much in the exhibit.	1	2	3	4	5
c. Reading the labels is useful to understanding the exhibit.	1	2	3	4	5
d. Visitors can learn something about Mars from the exhibit.	1	2	3	4	5
e. I feel the Living Quarters exhibit could be more detailed.	1	2	3	4	5

4. Based on your experience, please indicate your level of agreement:

	Mostly disagree		Neutral		Mostly agree
a. There is enough to do in this exhibit.	1	2	3	4	5
b. Talking with a facilitator is helpful.	1	2	3	4	5
c. The signs help visitors understand the exhibit better.	1	2	3	4	5
d. Visitors need more information to understand the exhibit.	1	2	3	4	5
e. I feel that learning occurs at this exhibit.	1	2	3	4	5

5. Please describe your personal understanding of the nature of science.

____

____

____

6. What scientific knowledge do you think visitors should learn from this exhibit?

____

____

____

7. What do you think is the main purpose of the Astronaut Training Exhibit?

____

____

____

Appendix III: Participant Consent Forms

University of Kansas and Science City

Adult Consent Form for Human Subjects Participating in a Research Study

The Department of Chemistry at the University of Kansas and personnel at Science City support the practice of protection for individuals participating in a research study. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study, and even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with these institutions and the services they may provide to you.

This document is to formally acknowledge your willingness to participate in the Heppert science education group study on learning. We are interested in studying how exhibits at Science City change or influence visitors' perceptions of science as well as knowledge gained through the experience. Due to the informal nature of science centers, content knowledge will not be specifically addressed and incorrect responses will not be used in any manner that could lead to you being personally identified.

As part of this study, you are asked to complete a survey about your experiences. The survey should take no more than ten minutes to complete. Please be assured that any personal information collected will be maintained in such a manner as to ensure privacy for the participants.

Your participation is important to this study. We thank you for taking a few minutes of your time to fill out the survey. If you would like any additional information regarding this study before, during, or after it is complete, feel free to contact either Joseph Heppert or myself, April French, by phone or email.

Sincerely,

Joseph Heppert
Principle Investigator
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
jheppert@ku.edu
(785) 864-2270

April French
Graduate Research Assistant
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
aprilf@ku.edu
(785) 864-3113

____________________________________ _______________

Signature of Participant — Date

With my signature, I affirm that I am at least 18 years of age and have received a copy of this consent form to keep.

University of Kansas and Science City

Parent/Guardian Consent Form for Human Subjects Participating in a Research Study

The Department of Chemistry at the University of Kansas and personnel at Science City support the practice of protection for individuals participating in a research study. The following information is provided for you to decide whether you wish to have your child participate in the present study. You may refuse to sign this form and not participate in this study, and even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with these institutions and the services they may provide to you.

This document is to formally acknowledge your willingness for your child to participate in the Heppert science education group study on learning. We are interested in studying how exhibits at Science City influence or change visitors' perceptions of science as well as knowledge gained through the experience. Due to the informal nature of science centers, content knowledge will not be specifically addressed and incorrect responses will not be used in a manner that could lead to you or your child being personally identifiable.

As part of this study, your child will be asked to complete a survey about his/her experiences.. The survey should take no more than ten minutes to complete. Please be assured that any personal information collected will be maintained in such a manner as to ensure privacy for the participants.

Your child's participation is important to this study. We thank you for taking a few minutes of your time to fill out the survey with your child. If you would like any additional information regarding this study before, during, or after it is complete, feel free to contact either Joseph Heppert or myself, April French, by phone or email.

Sincerely,

Joseph Heppert
Principle Investigator
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
jheppert@ku.edu
(785) 864-2270

April French
Graduate Research Assistant
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
aprilf@ku.edu
(785) 864-3113

Name of participant: ______________________________

______________________________________ ________________

Signature of Parent/Guardian Date

With my signature, I affirm that I am at least 18 years of age and have received a copy of this consent form to keep.

University of Kansas and Science City

Child Assent Form

Learning at Science City

1. We are studying learning at Science City. As part of the study, we'd like your opinion on the exhibit you just finished viewing.
2. Please talk this over with your parents before you decide whether or not to participate. Your parents will be asked to give their permission for you to take part in this study.
3. If you have any questions at any time, please ask.
4. You will be asked to answer some questions. You can answer them on your own or have your parents help you. We want to know what you like about the exhibit, what you remember about the exhibit and how much of a good time you had playing with the exhibit.
5. Your participation will help make the exhibits here at Science City be more fun and educational for kids.

You are making a decision whether or not to be in this study. You and your parents will be given a copy of this assent form to keep.

Sincerely,

Joseph Heppert
Principle Investigator
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
jheppert@ku.edu
(785) 864-2270

April French
Graduate Research Assistant
Department of Chemistry, 2010 Malott Hall
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
aprilf@ku.edu
(785) 864-3113

__________________ __________________

Initials of Parent/Guardian **Date**

With my initials, I affirm that I am at least 18 years of age and have received a copy of this consent form to keep and have discussed participation with my child.

Appendix IV: Letters of Introduction for Follow-Up Surveys - USPS

April, 2005

What did you get out of your visit to Science City?

Hello!

I hope you enjoyed your visit to Kansas City's Science City a few months back. You may have forgotten that you took a survey sponsored by the University of Kansas' Center for Environmentally Beneficial Catalysis (CEBC) and Science City related to your experiences at Science City. It is ok if you did and I'd like to refresh your memory and thank you for filling out the first survey. Your response has helped us determine that learning ***is*** occurring at Science City!

I'm conducting a follow-up survey to find out what you remember about your visit. Please complete the survey found at:

http://129.237.27.25/~gwebber/atc/atcsurvey.html

by entering the link into your internet browser. Please include the last 4 digits of your home phone number at the top of the survey so we can link this survey with the one you previously completed. You may also complete the copy enclosed and return it to me using the self-addressed stamped envelope also included.

By completing the survey, you consent to having the information collected included in a research study of the educational environment at Science City. Please keep in mind that the information collected will be kept confidential and your name does not need to be included on the survey, as outlined in the consent form you received when you completed our first survey.

Please feel free to contact me if you have any questions regarding the survey, the information collected from it, or would like to obtain an additional copy of the consent form.

Sincerely,

April French
Department of Chemistry, 2010 Malott
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
aprilf@ku.edu
(785) 864-3113

Enclosures:
Survey; SASE

Letters of Introduction for Follow-Up Surveys – Email

April, 2005

What did you get out of your visit to Science City?

Hello!

I hope you enjoyed your visit to Kansas City's Science City a few months back. You may have forgotten that you took a survey sponsored by the University of Kansas' Center for Environmentally Beneficial Catalysis (CEBC) and Science City related to your experiences at Science City. It is ok if you did and I'd like to refresh your memory and thank you for filling out the first survey. Your response has helped us determine that learning ***is*** occurring at Science City!

I'm conducting a follow-up survey to find out what you remember about your visit. Please complete the survey found at:

http://129.237.27.25/~gwebber/atc/atcsurvey.html

by clicking on the link provided or copying and pasting the link into your internet browser. Please include the last 4 digits of your home phone number (----) at the top of the survey so we can link this survey with the one you previously completed.

By completing the survey, you consent to having the information collected included in a research study of the educational environment at Science City. Please keep in mind that the information collected will be kept confidential and your name does not need to be included on the survey, as outlined in the consent form you received when you completed our first survey.

Please feel free to contact me if you have any questions regarding the survey, the information collected from it, or would like to obtain an additional copy of the consent form.

Sincerely,

April French
Department of Chemistry, 2010 Malott
1251 Wescoe Hall Drive
University of Kansas
Lawrence, KS 66045-7582
aprilf@ku.edu
(785) 864-3113

Appendix V: Learning Levels Rubric for *Astronaut Training Center*

Learning Levels Rubric — ***Astronaut Training Center***

Learning Level:	Behaviors:	Responses are:	Examples (by question):	Misconceptions
One:	**Identifying**	One word statements Few associations to exhibit content Connections to content miss the point of the exhibit	7. Living on a space shuttle. Size of a space suit. Space. Mars. 8. Life in space. How Mars is different from Earth. 9. Mars. Space shuttle. Space suits. Astronauts	Many misconceptions in responses.
Two:	*Describing*	Correct connections to visible exhibit characteristics Connections to personal experience based on visible exhibit characteristics, not concepts	7. Learned how Mars soil is more magnetic than Earth's. Felt how difficult it is to manipulate robots that cannot be seen directly. 8. Exhibit show how astronauts live and interact differently with their environment. 9. Seeing video of the Mars Rovers, the comet hitting Jupiter, landing on the Moon, etc. on TV.	Misconceptions are present, but not extensive.
Three:	*Interpreting and Applying*	Correct statement of concepts behind exhibits Connection of exhibit concepts of life experiences	7. Learned about how life is different living in space. Do to the gravity difference, astronauts need special bed, bathrooms, and food to survive. Mars has a different environment than Earth due to differences in soil content. 8. The exhibit shows how living in space or on Mars is different from living on Earth. Astronauts need to have everything in their environment supplied for then, because they can't run to Wal-mart, etc. for stuff. 9. The different soils allow for different plants to grow or not grow.	Little to no misconceptions in responses.

Adapted from: Borun, M., M. B. Chambers, et al. (1997). "Enhancing Family Learning Through Exhibits." Curator **40**(4): 279-295.
7. Do you feel you learned anything from the exhibit?
8. What do you think the exhibit is trying to show?
9. What comes to mind when you think about this exhibit?

Appendix VI: Behavior Rubric

Behavior Rubric

Group #: _____ Time: start: ______ finish: _______ Date: ___________

Exhibit: ATC NC CL

Group Description: Adults: # ______, gender: ______________ ethnicity: W B A H O

Children: # _______, gender: ____________ ethnicity: W B A H O

Age: 1 -5 6 -10 11 -15 16-18 19-30 31-40 41 – 50 51+

Composition: Family Friends School

	A. Behavior	B. Conversation	C. Interaction
1. Attention	Points to station D A C E A C F A C G A C H A C I A C	Calls someone over D A C → A C E A C → A C F A C → A C G A C → A C H A C → A C I A C → A C	Asks questions D A C → A C E A C → A C F A C → A C G A C → A C H A C → A C I A C → A C
2. Active	Reads signage D A C → A C E A C → A C F A C → A C G A C → A C H A C → A C I A C → A C	Expresses Like / Dislike D A C → A C L D E A C → A C L D F A C → A C L D G A C → A C L D H A C → A C L D I A C → A C L D	Visitor manipulates exhibit : D A C E A C F A C G A C H A C I A C
3. Passive	Follows exhibit sequence 1 2 3 4 5	Non-exhibit related A C → A C 1 2 3 4 5	Watches other visitors interact D A C → A C E A C → A C F A C → A C G A C → A C H A C → A C I A C → A C

Likert Scale: 1 = Never, 2 = rarely, 3 = some, 4 = frequently, 5 = very frequently

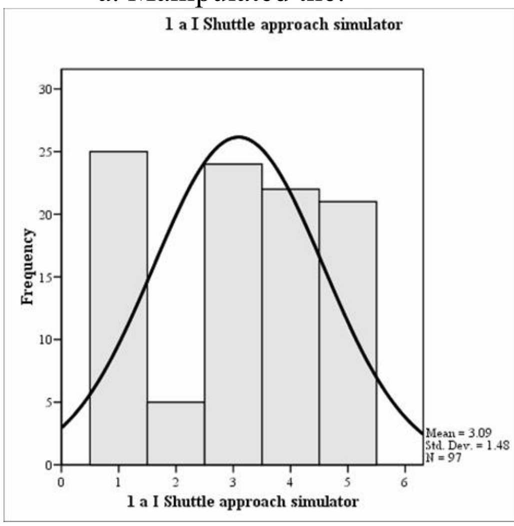
Designations: A = adult, C = child

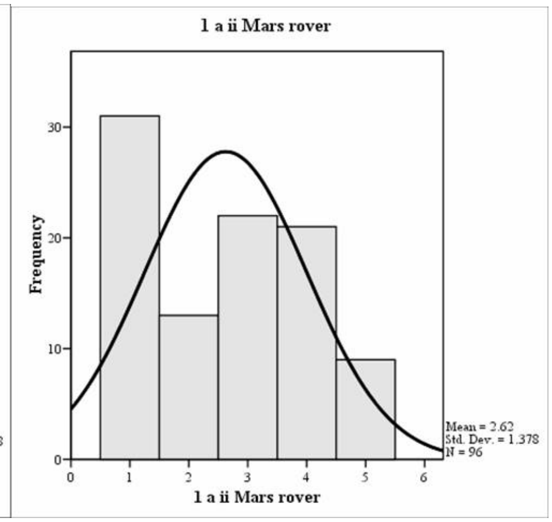
D = sketch artist, shuttle simulator, specimens; E = fingerprint analysis, Mars rover, reptiles;
F = fiber analysis, compatibility test/make repairs, mammals;
G = hair sample, robotic arm, amphibians; H = writing analysis, fitness test, animal puppets
I = Dizziness challenge

Appendix VII: Initial Visitor Survey Frequency Data

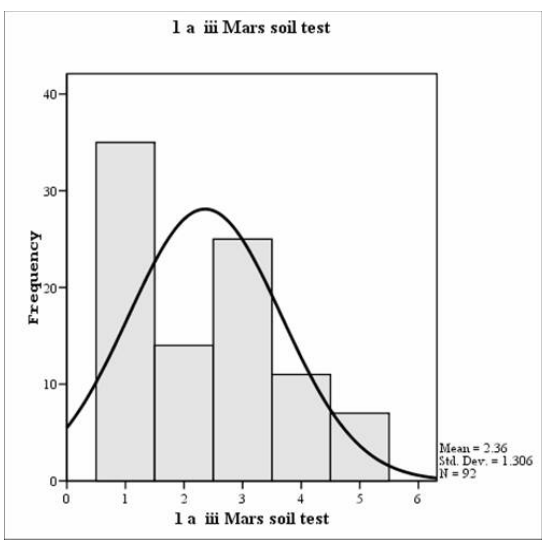
Section I.
A: Interaction

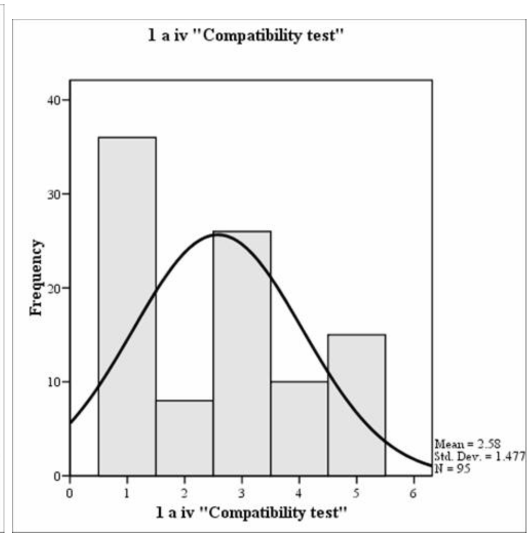
1. Please circle how much you:
   a. Manipulated the:

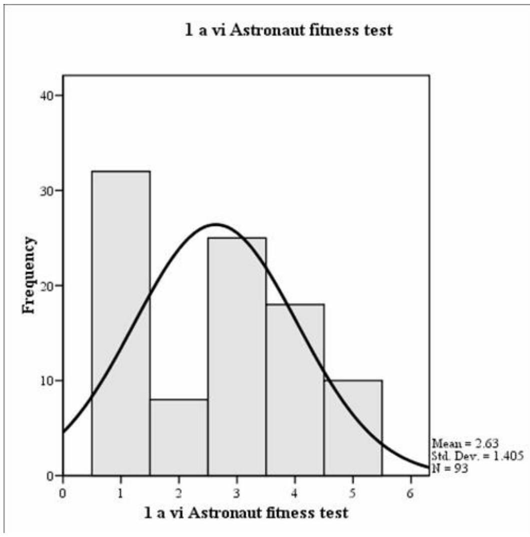


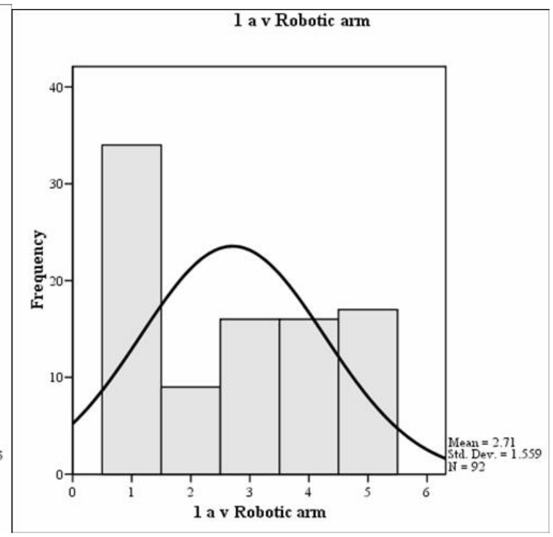


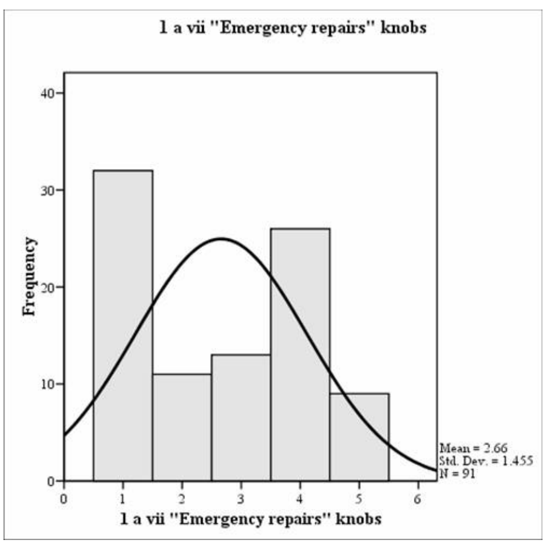
Response coding for question 1:
1 = Not at All; 2; 3 = Some; 4; 5 = A lot



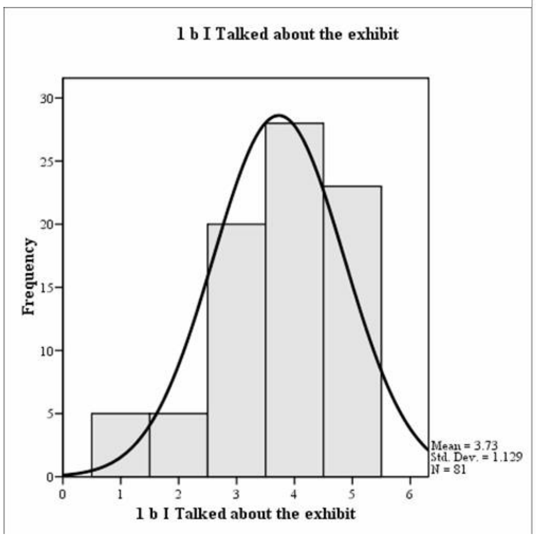


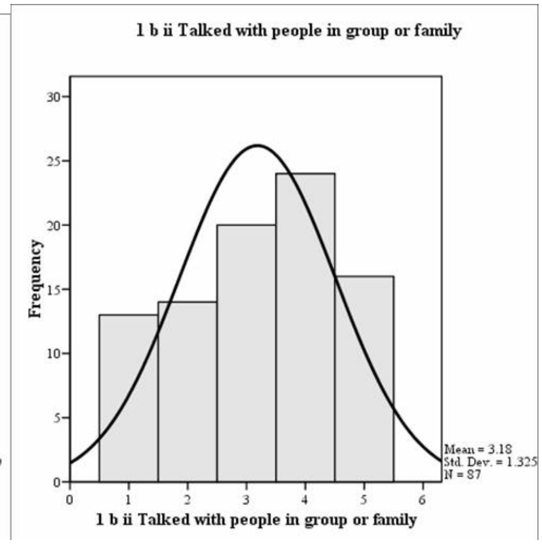

1 a vi Astronaut fitness test
Frequency
Mean = 2.63
Std. Dev. = 1.405
N = 93
1 a vi Astronaut fitness test

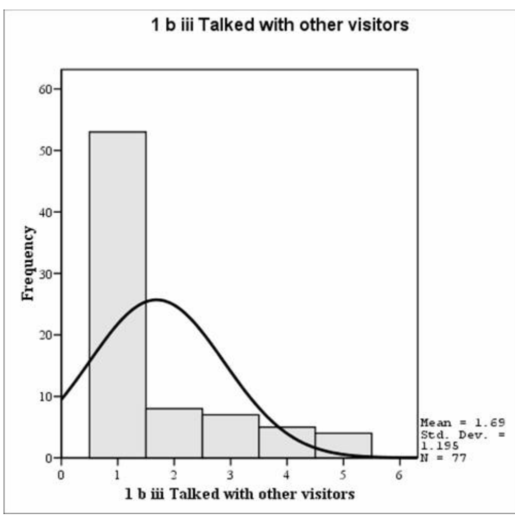

1 a v Robotic arm
Frequency
Mean = 2.71
Std. Dev. = 1.559
N = 92
1 a v Robotic arm

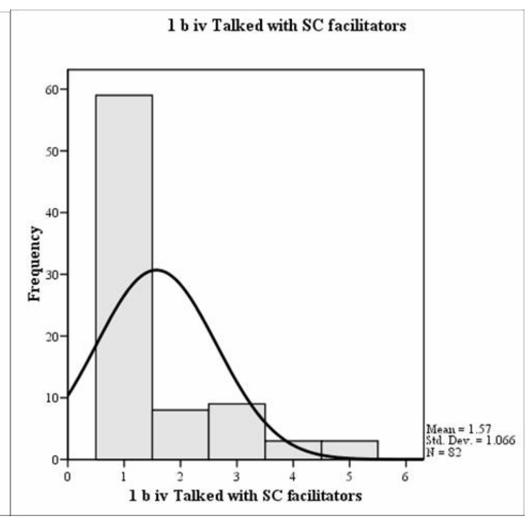

1 a vii "Emergency repairs" knobs
Frequency
Mean = 2.66
Std. Dev. = 1.455
N = 91
1 a vii "Emergency repairs" knobs

b. talked about the exhibit:

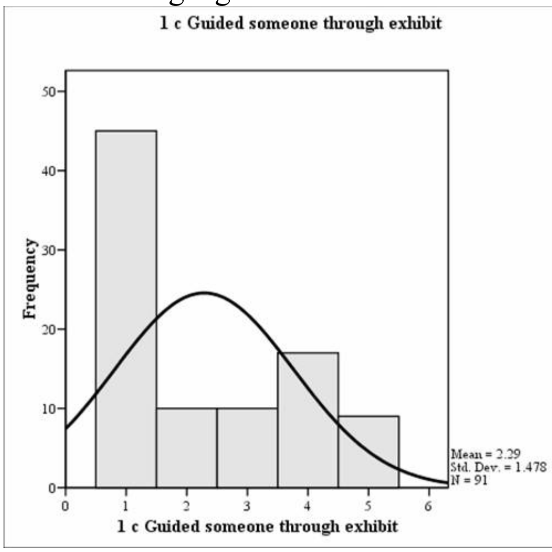


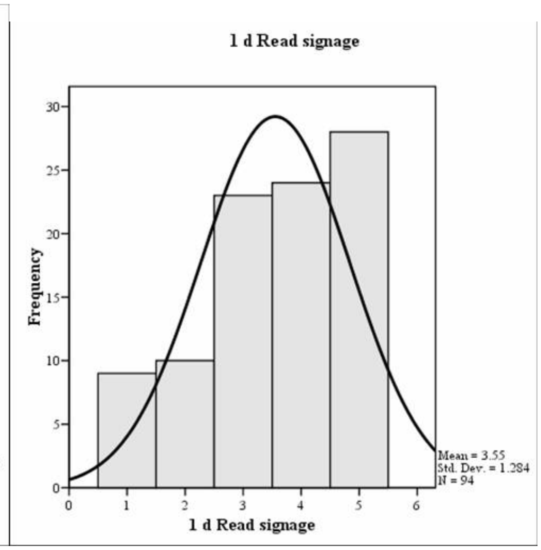




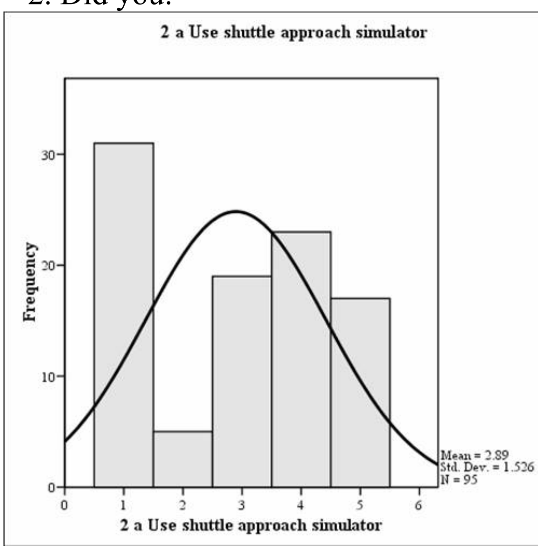


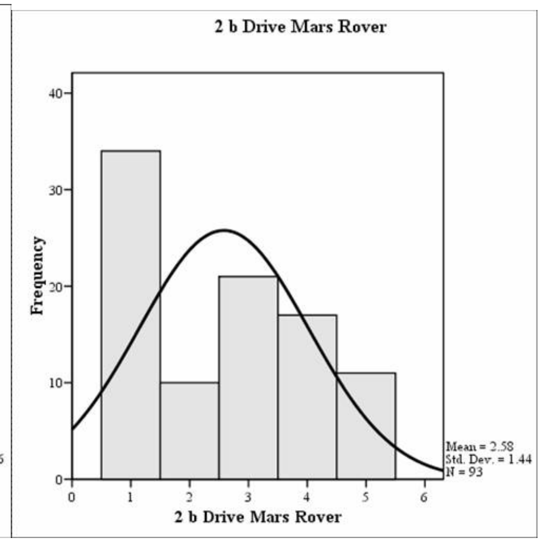
c. guided someone through the exhibit.
d. read signage next to the stations.





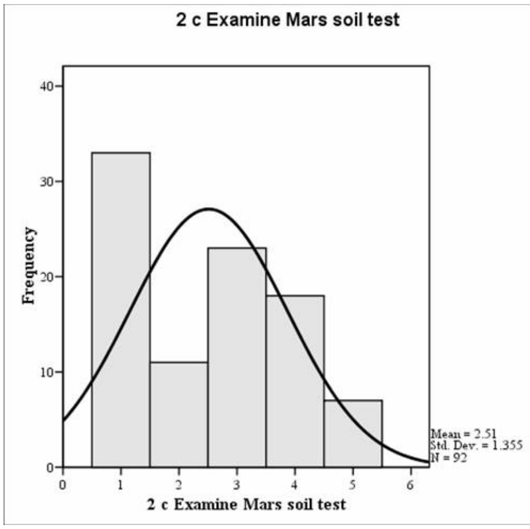
2. Did you:

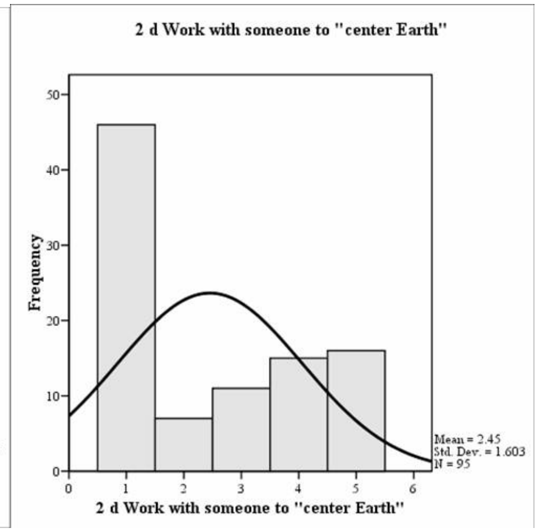


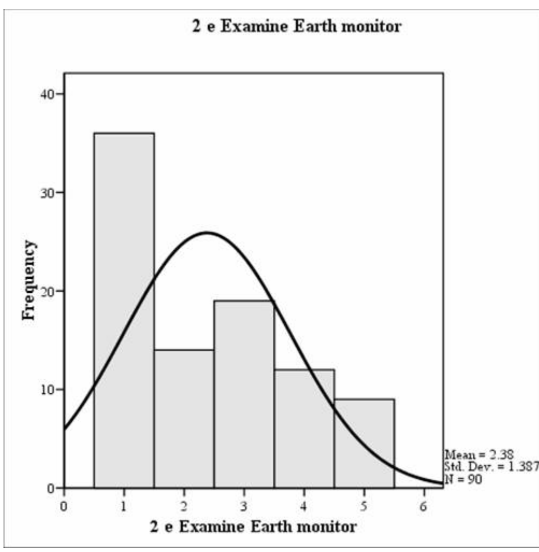


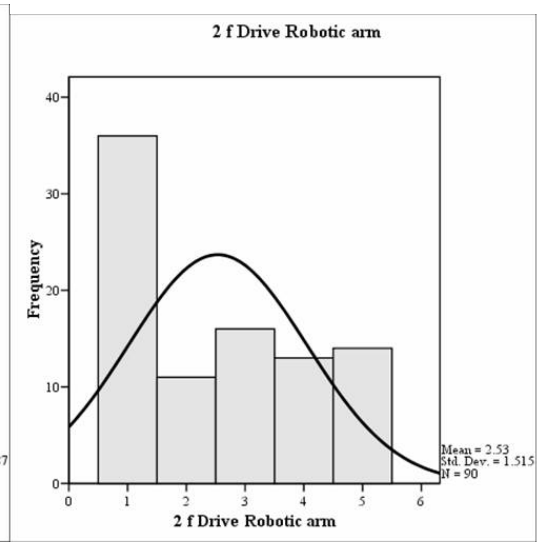
Response coding for question 2:

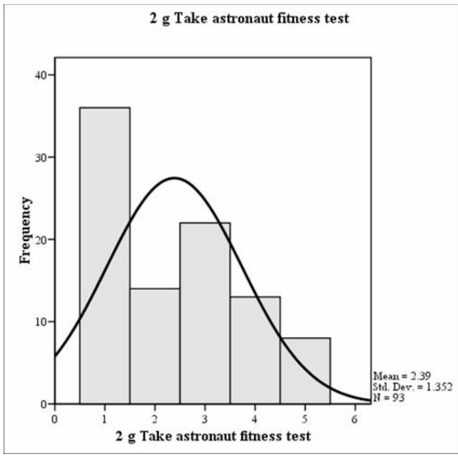
1 = Not at All; 2; 3 = Some; 4; 5 = A lot

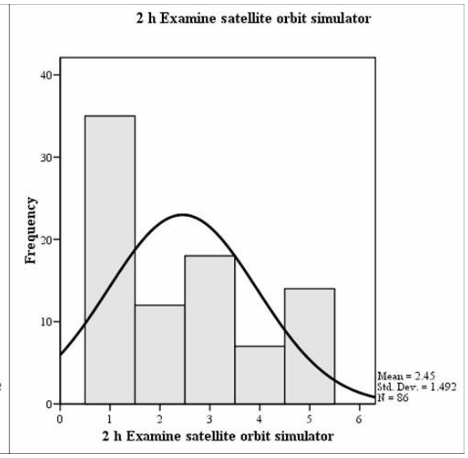

2 c Examine Mars soil test
Frequency
Mean = 2.51
Std. Dev. = 1.355
N = 92
2 c Examine Mars soil test

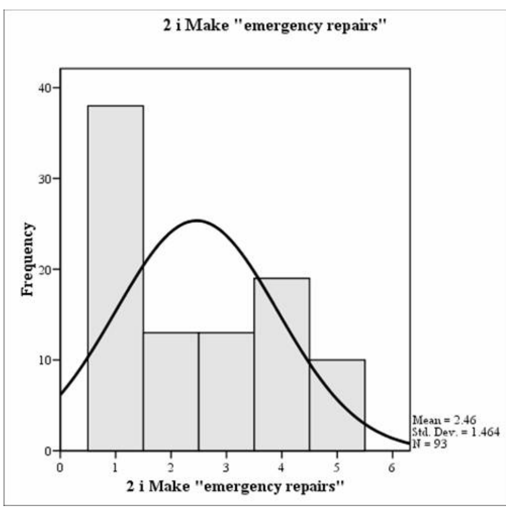

2 d Work with someone to "center Earth"
Frequency
Mean = 2.45
Std. Dev. = 1.603
N = 95
2 d Work with someone to "center Earth"

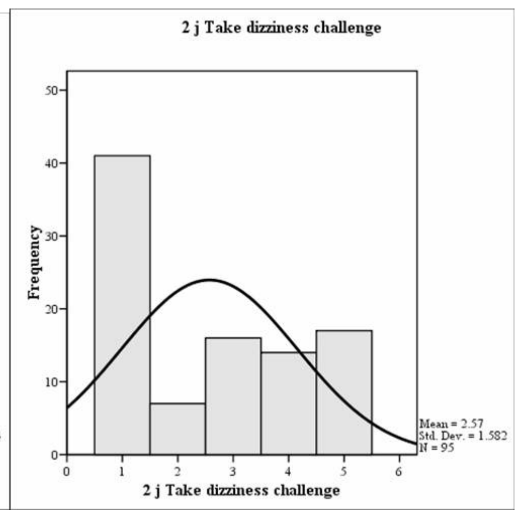

2 e Examine Earth monitor
Frequency
Mean = 2.38
Std. Dev. = 1.387
N = 90
2 e Examine Earth monitor

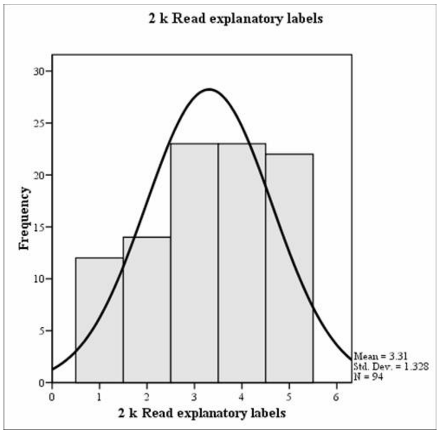

2 f Drive Robotic arm
Frequency
Mean = 2.53
Std. Dev. = 1.515
N = 90
2 f Drive Robotic arm


2 g Take astronaut fitness test
Frequency
Mean = 2.39
Std. Dev. = 1.352
N = 93
2 g Take astronaut fitness test

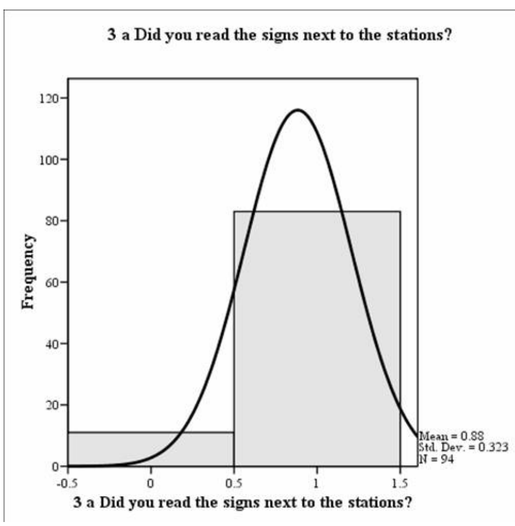

2 h Examine satellite orbit simulator
Frequency
Mean = 2.45
Std. Dev. = 1.492
N = 86
2 h Examine satellite orbit simulator

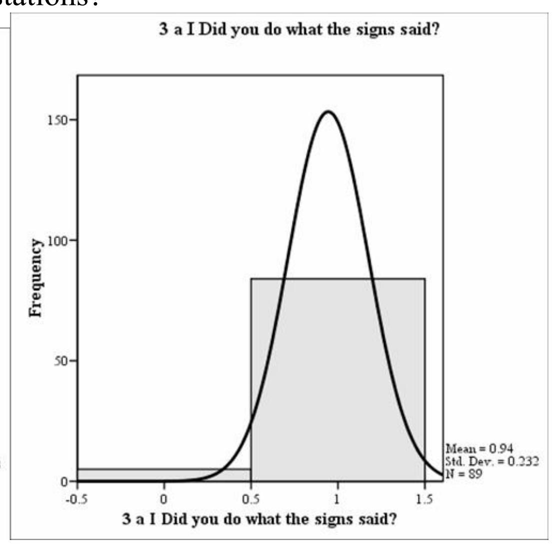

2 i Make "emergency repairs"
Frequency
Mean = 2.46
Std. Dev. = 1.464
N = 93
2 i Make "emergency repairs"


2 j Take dizziness challenge
Frequency
Mean = 2.57
Std. Dev. = 1.582
N = 95
2 j Take dizziness challenge



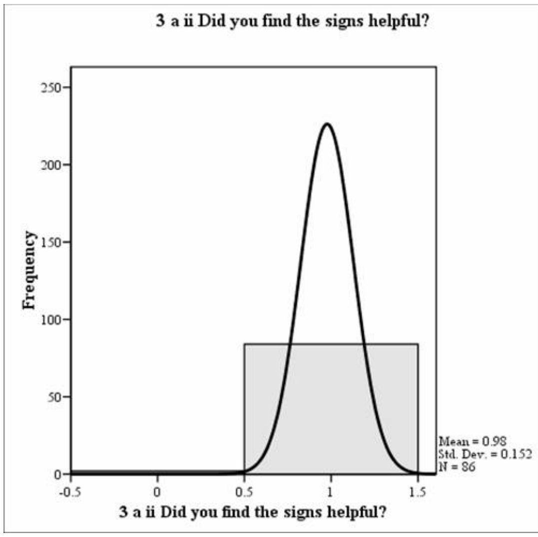
3. Did you read the signs next to the stations?

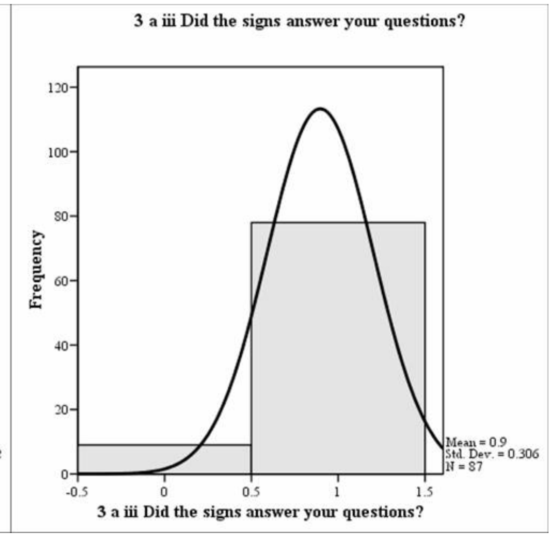


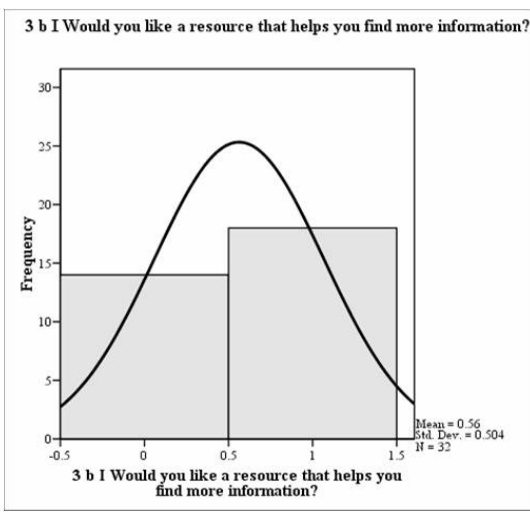


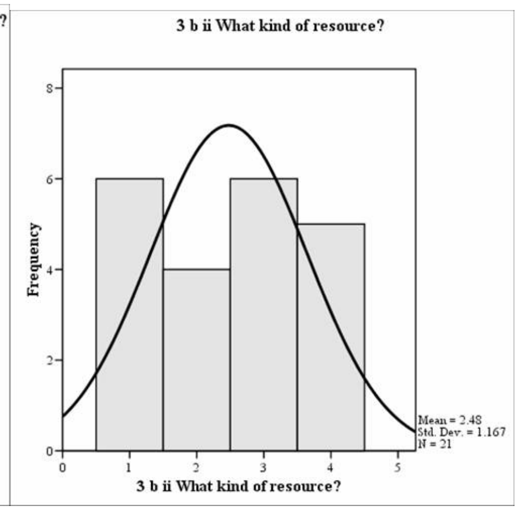
Response coding for question 3:

0 = No; 1 = Yes







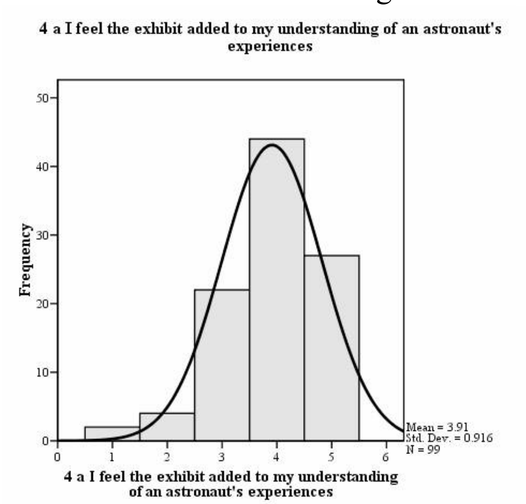


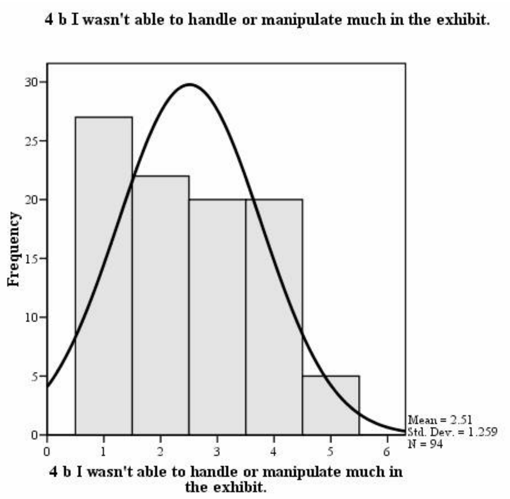
Response coding for question 3 b ii:

1 = Booklet   2 = Internet website   3 = signs   4 = other

B. Visitor Attitude

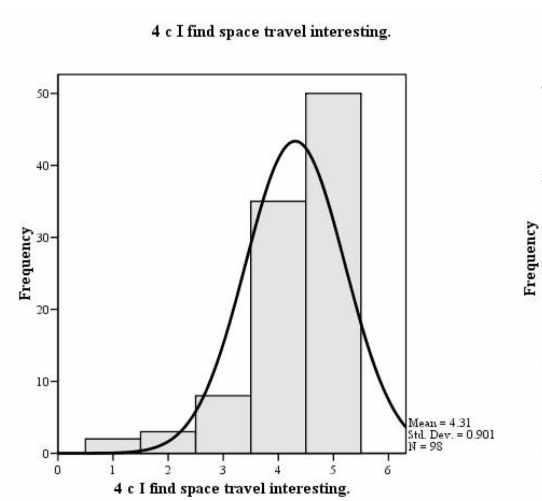
4. Please indicate level of agreement:

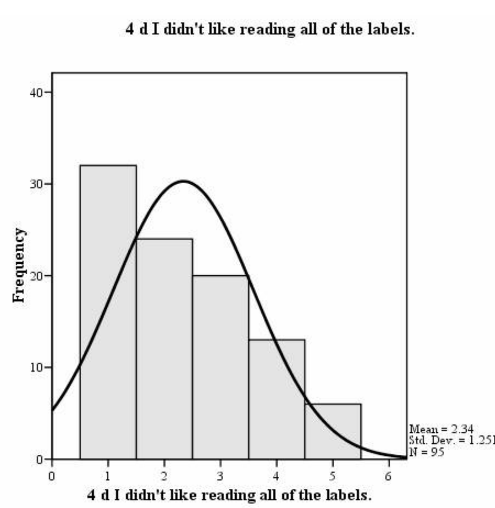


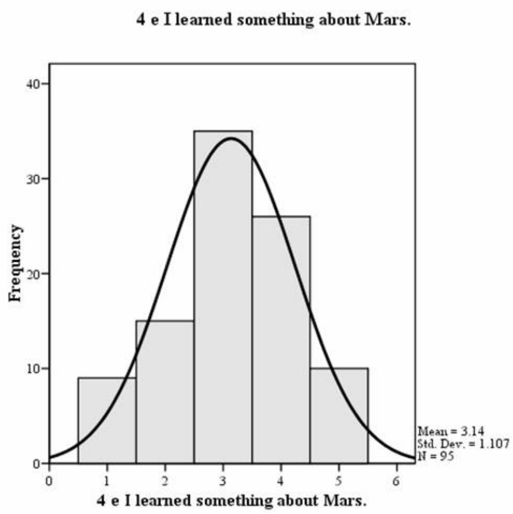


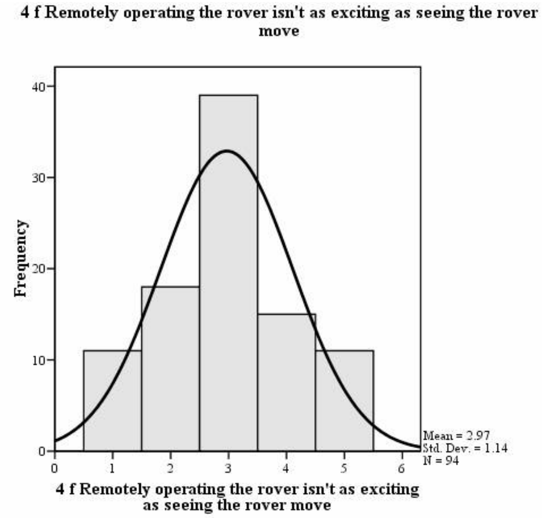
Response coding for question 4:

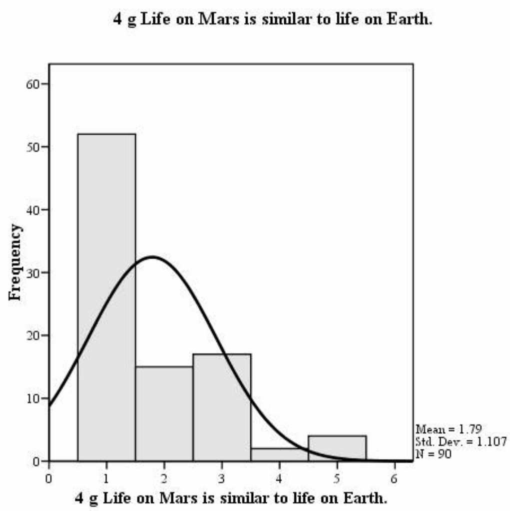
1 = Mostly disagree 2 3 = Neutral 4 5 = Mostly agree

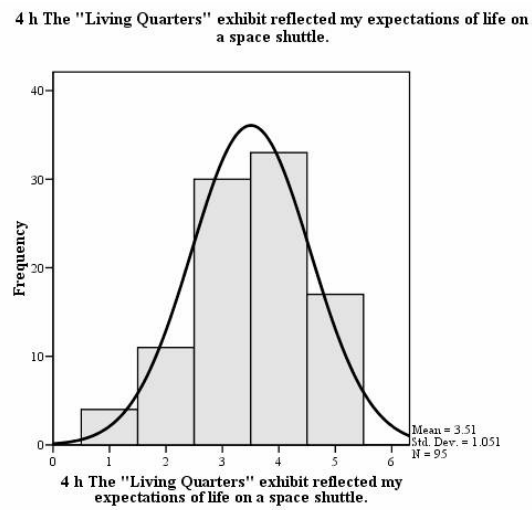


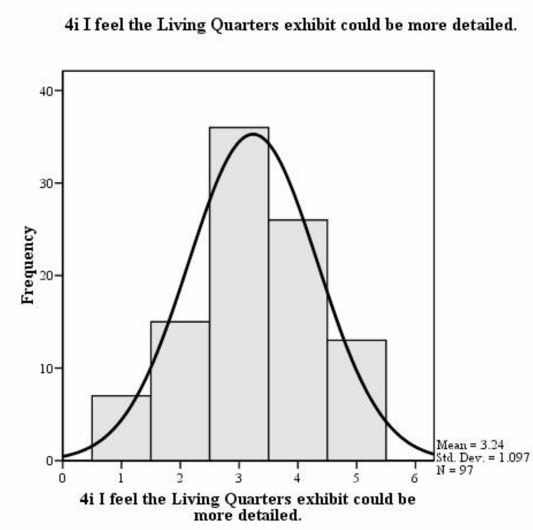


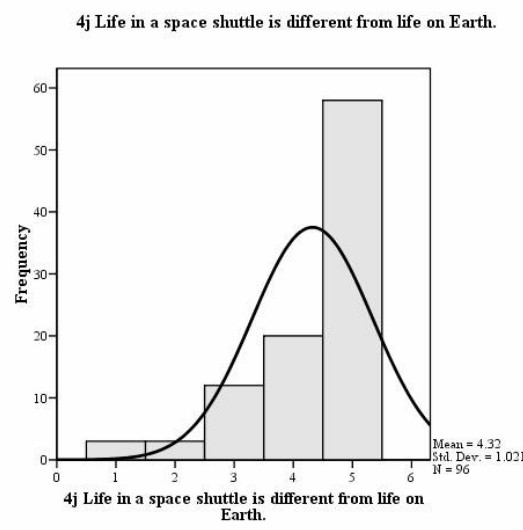

4 e I learned something about Mars.
Frequency
Mean = 3.14
Std. Dev. = 1.107
N = 95
4 e I learned something about Mars.


4 f Remotely operating the rover isn't as exciting as seeing the rover move
Frequency
Mean = 2.97
Std. Dev. = 1.14
N = 94
4 f Remotely operating the rover isn't as exciting as seeing the rover move

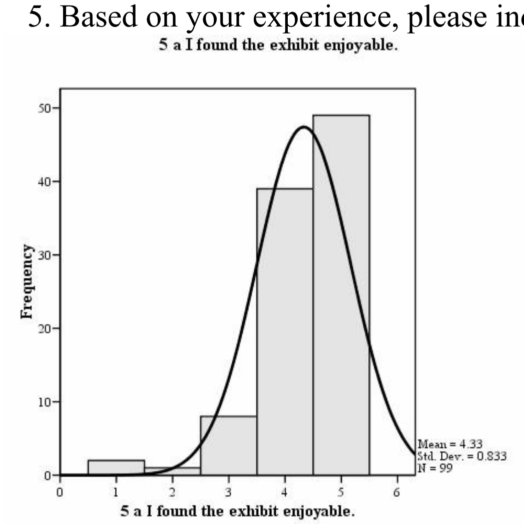

4 g Life on Mars is similar to life on Earth.
Frequency
Mean = 1.79
Std. Dev. = 1.107
N = 90
4 g Life on Mars is similar to life on Earth.

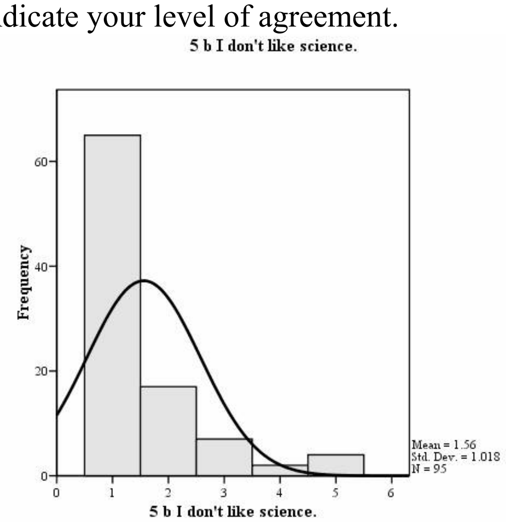

4 h The "Living Quarters" exhibit reflected my expectations of life on a space shuttle.
Frequency
Mean = 3.51
Std. Dev. = 1.051
N = 95
4 h The "Living Quarters" exhibit reflected my expectations of life on a space shuttle.





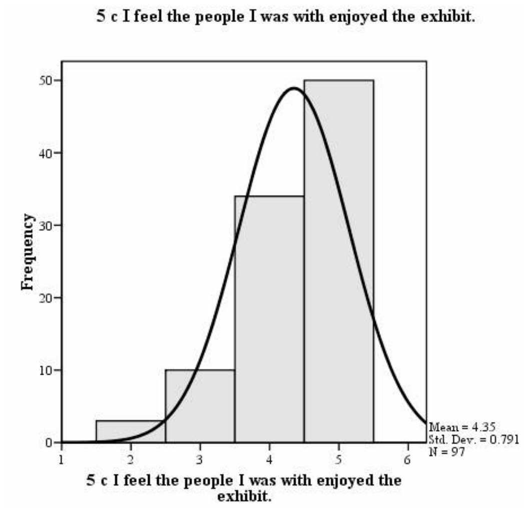
5. Based on your experience, please indicate your level of agreement.

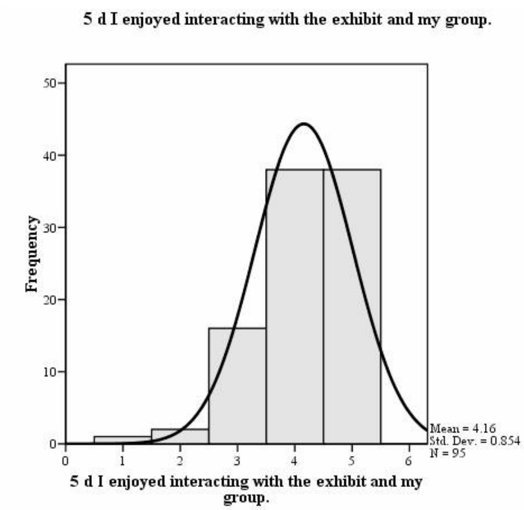


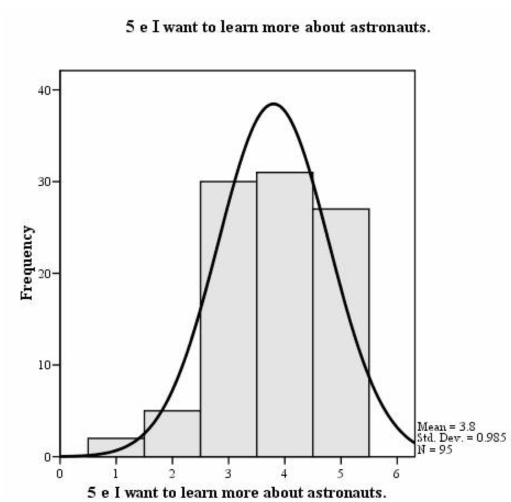


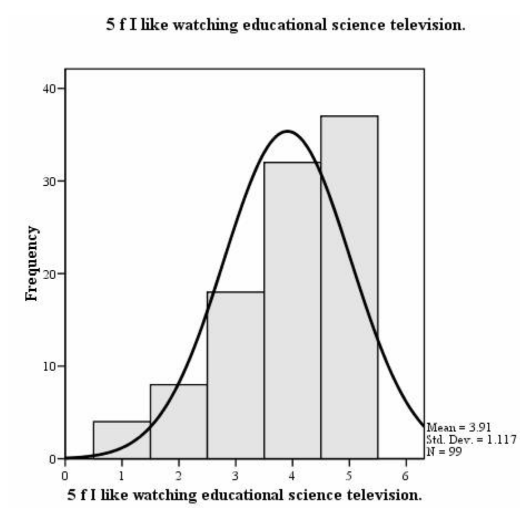
Response coding for question 5:

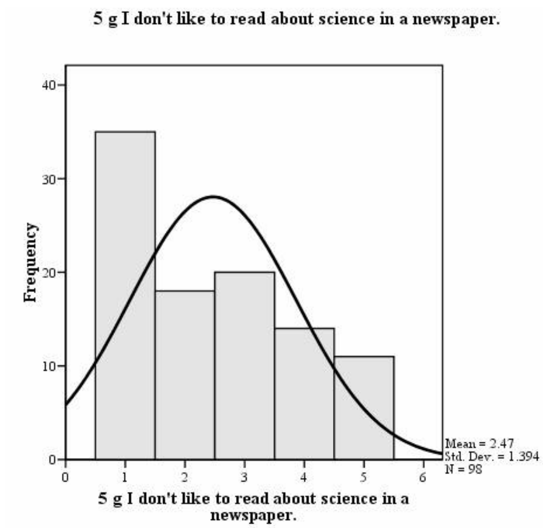
1 = Mostly disagree 2 3 = Neutral 4 5 = Mostly agree

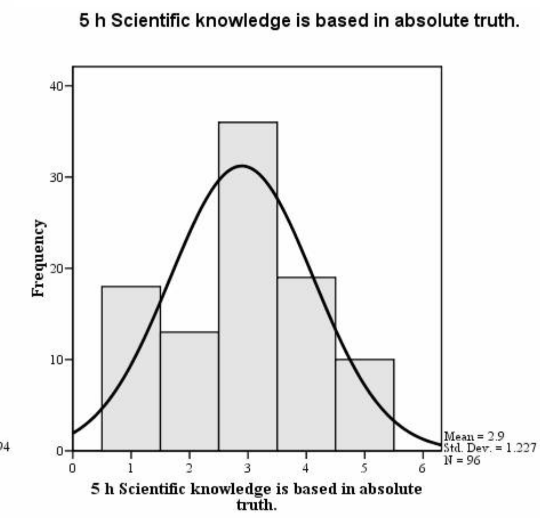

5 c I feel the people I was with enjoyed the exhibit.
Frequency
Mean = 4.35
Std. Dev. = 0.791
N = 97
5 c I feel the people I was with enjoyed the exhibit.

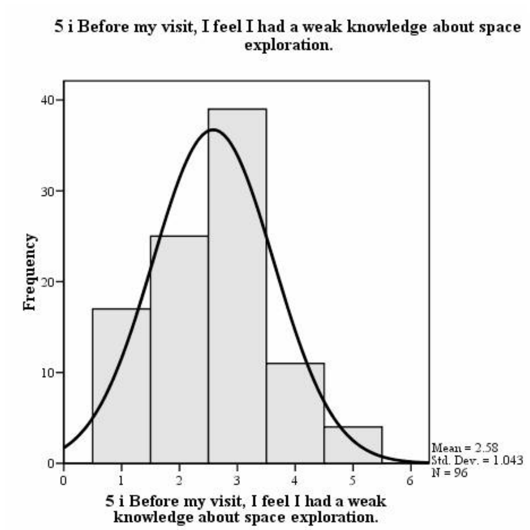

5 d I enjoyed interacting with the exhibit and my group.
Frequency
Mean = 4.16
Std. Dev. = 0.854
N = 95
5 d I enjoyed interacting with the exhibit and my group.

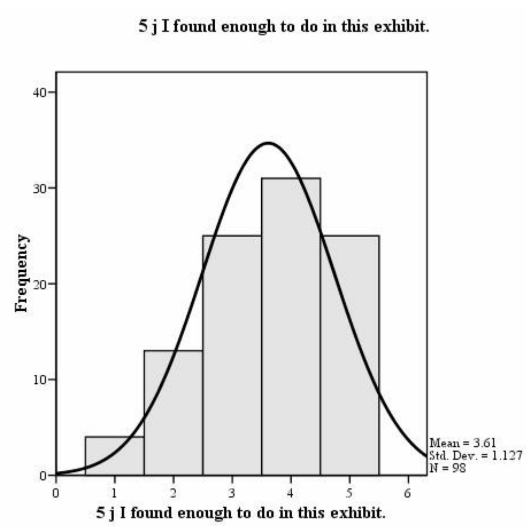

5 e I want to learn more about astronauts.
Frequency
Mean = 3.8
Std. Dev. = 0.985
N = 95
5 e I want to learn more about astronauts.

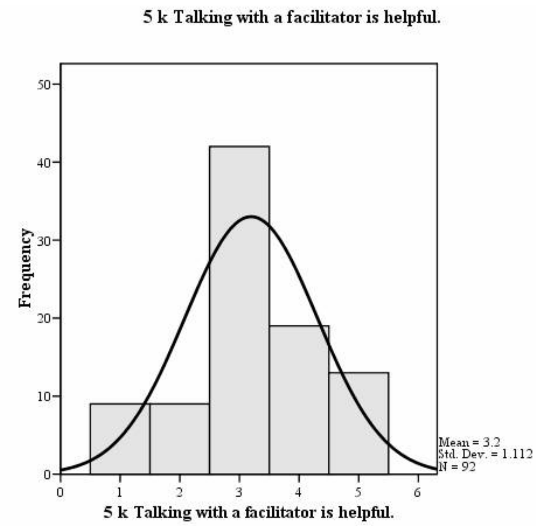

5 f I like watching educational science television.
Frequency
Mean = 3.91
Std. Dev. = 1.117
N = 99
5 f I like watching educational science television.

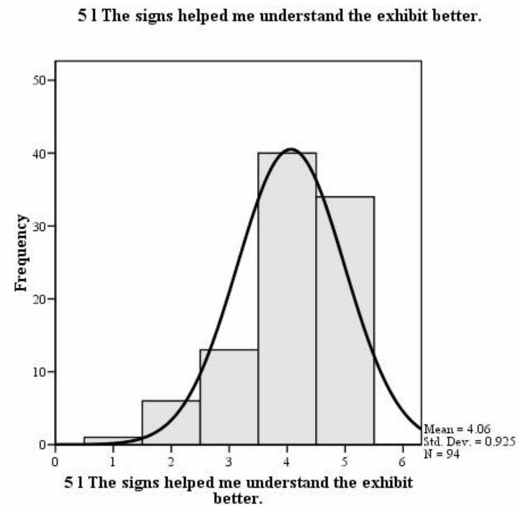

5 g I don't like to read about science in a newspaper.
Frequency
Mean = 2.47
Std. Dev. = 1.394
N = 98
5 g I don't like to read about science in a newspaper.

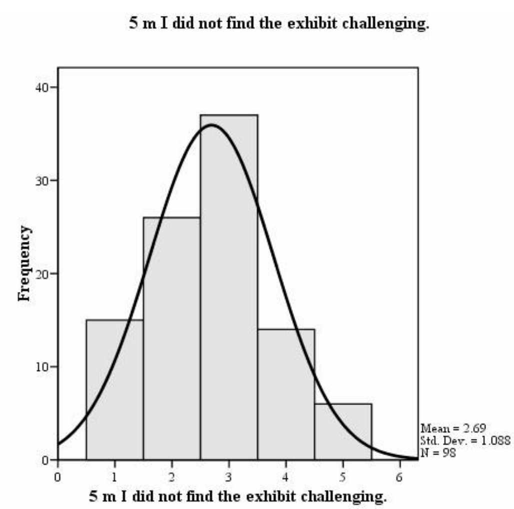

5 h Scientific knowledge is based in absolute truth.
Frequency
Mean = 2.9
Std. Dev. = 1.227
N = 96
5 h Scientific knowledge is based in absolute truth.

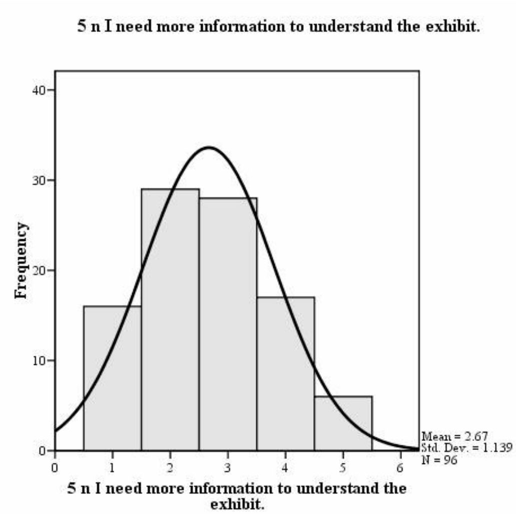

5 i Before my visit, I feel I had a weak knowledge about space exploration.
Frequency
Mean = 2.58
Std. Dev. = 1.043
N = 96
5 i Before my visit, I feel I had a weak knowledge about space exploration.

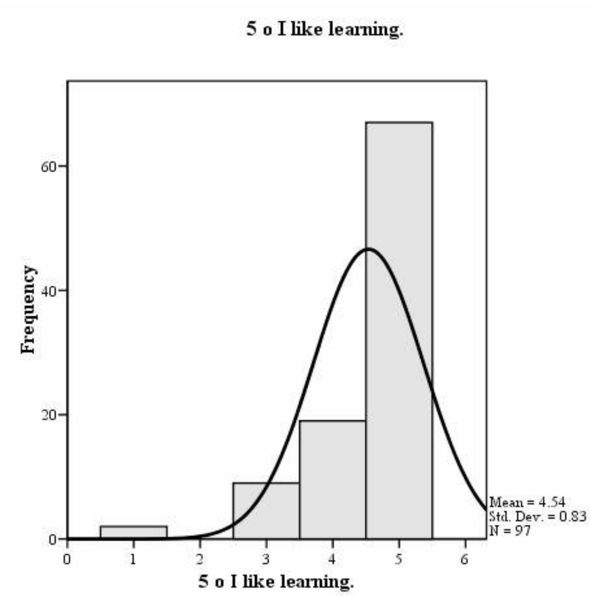

5 j I found enough to do in this exhibit.
Frequency
Mean = 3.61
Std. Dev. = 1.127
N = 98
5 j I found enough to do in this exhibit.


5 k Talking with a facilitator is helpful.
Frequency
Mean = 3.2
Std. Dev. = 1.112
N = 92
5 k Talking with a facilitator is helpful.

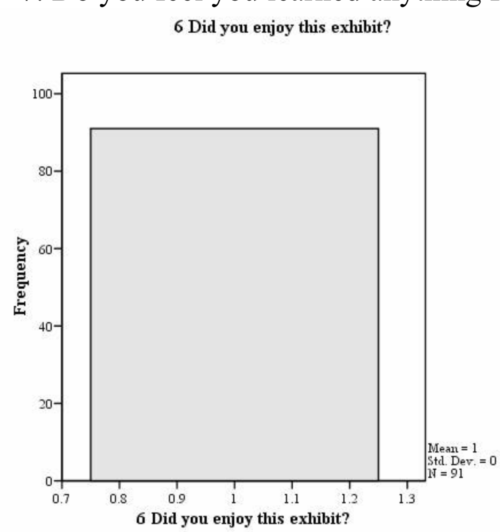

5 l The signs helped me understand the exhibit better.
Frequency
Mean = 4.06
Std. Dev. = 0.925
N = 94
5 l The signs helped me understand the exhibit better.

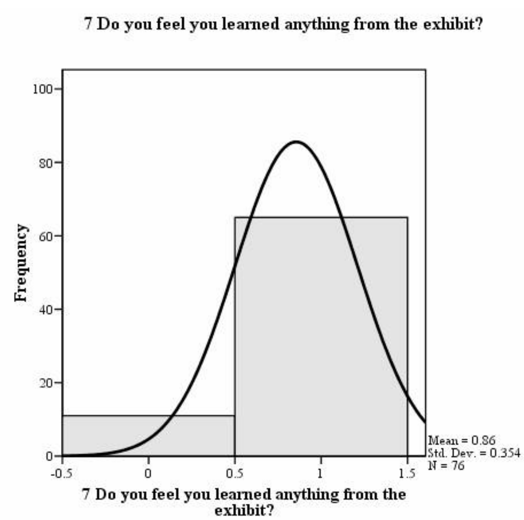

5 m I did not find the exhibit challenging.
Frequency
Mean = 2.69
Std. Dev. = 1.088
N = 98
5 m I did not find the exhibit challenging.


5 n I need more information to understand the exhibit.
Frequency
Mean = 2.67
Std. Dev. = 1.139
N = 96
5 n I need more information to understand the exhibit.



6. Did you enjoy this exhibit?
7. Do you feel you learned anything from the exhibit?

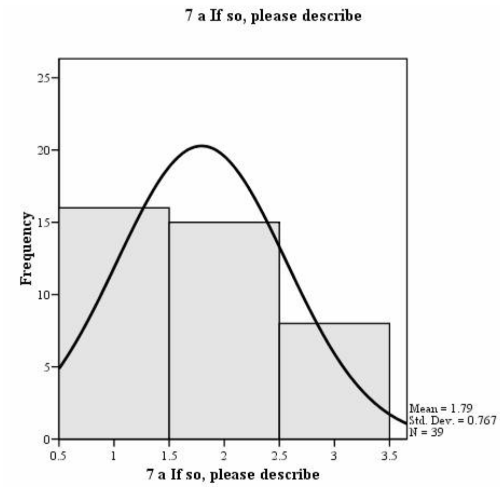


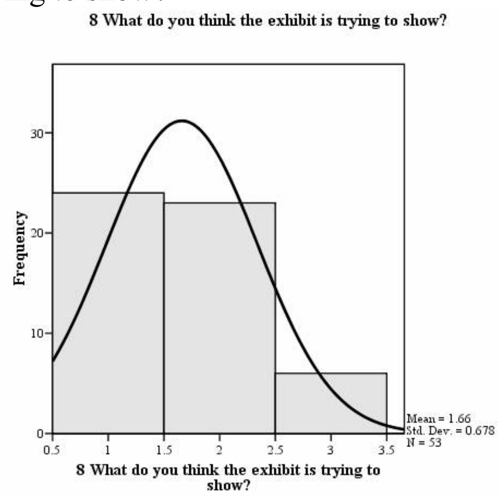


Response coding for question 6 and 7:
0 = No; 1 = Yes

7a. If so, please describe:

8. What do you think the exhibit is trying to show?

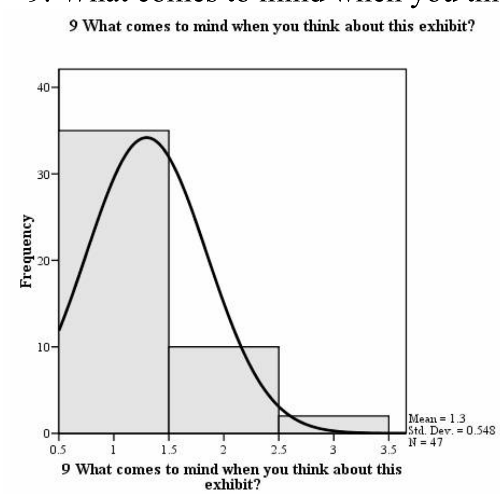




Response coding for question 7a, 8, and 9:

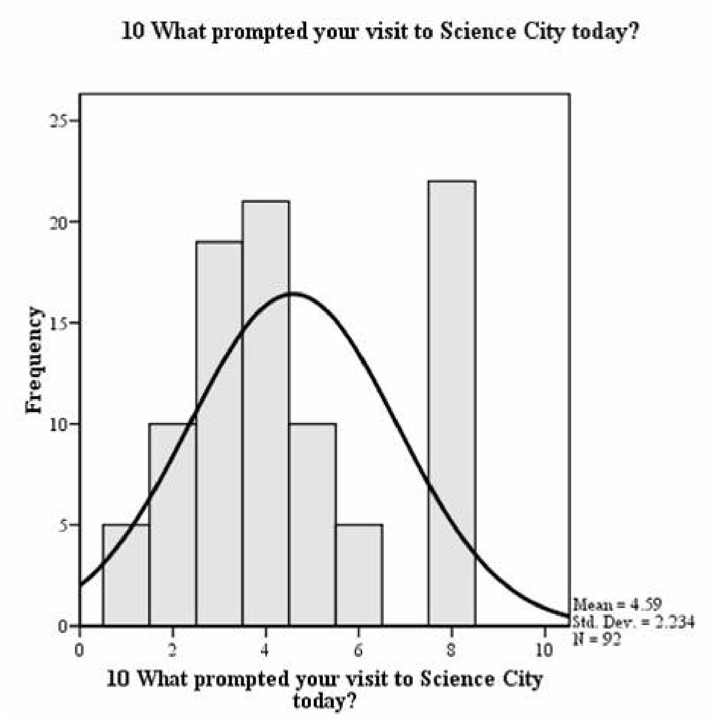
1 = Identifying 2 = Describing 3 = Interpreting and Applying

9. What comes to mind when you think about this exhibit?



Section II. Demographics

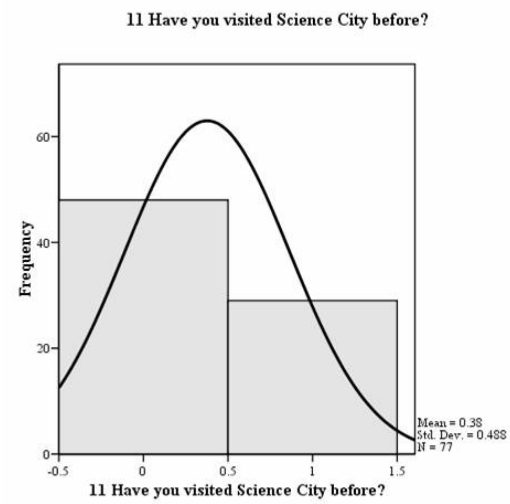
10. What prompted your visit to Science City today?

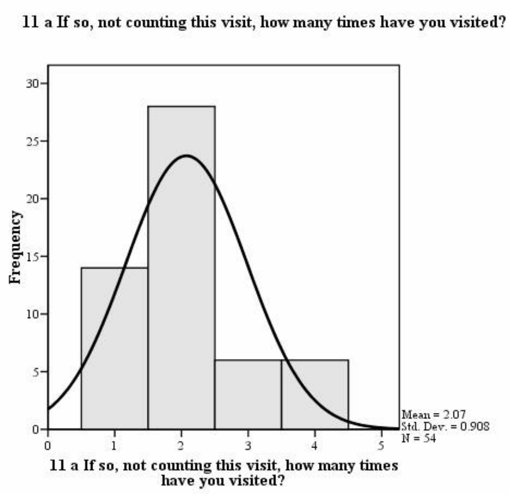


Response coding for question 10:

1 = Brought out-of-town company
2 = Are out-of-town company
3 = Wanted to do something educational with children
4 = Wanted to see Science City
5 = Recommended by a friend
6 = Read about Science City in a newspaper, magazine, or tour guide
7 = Heard a TV or radio ad
8 = other

11. Have you visited Science City before?
11a. If so, not counting this visit, how many times in the past year have you visited?





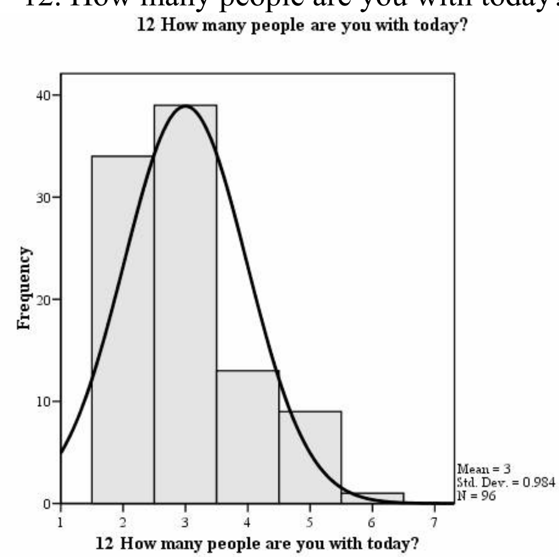
Response coding for question 11:

0 = No; 1 = Yes

Response coding for question 11a:

1 = 0 2 = 1 – 2 3 = 3 – 4 4 = 5 +

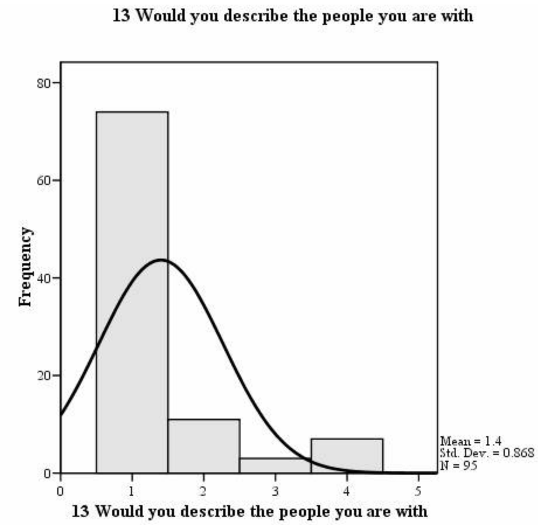
12. How many people are you with today?

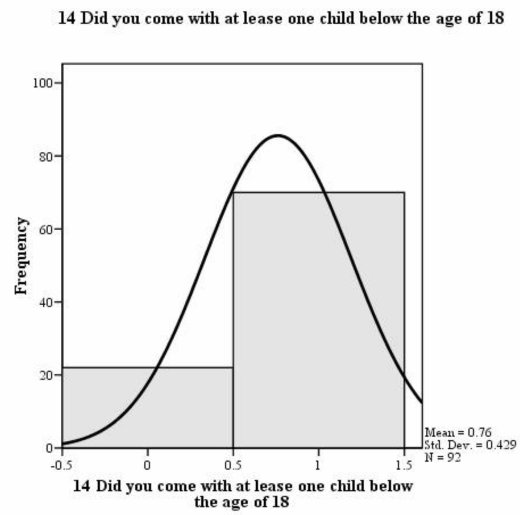


Response coding for question 12:

1 = 0 2 = 1 – 2 3 = 3 – 4 4 = 5 – 6 5 = 7 +

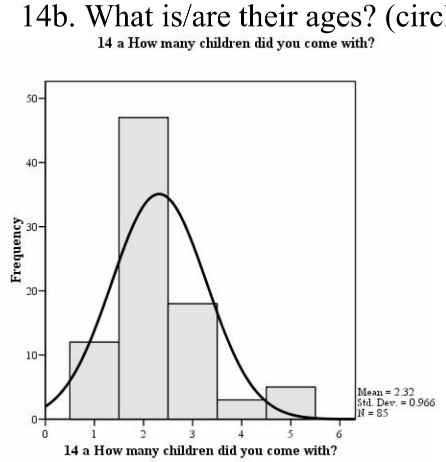
13. Would you describe the people you are with as (circle one):
14. Did you come with at least one child below the age of 18?





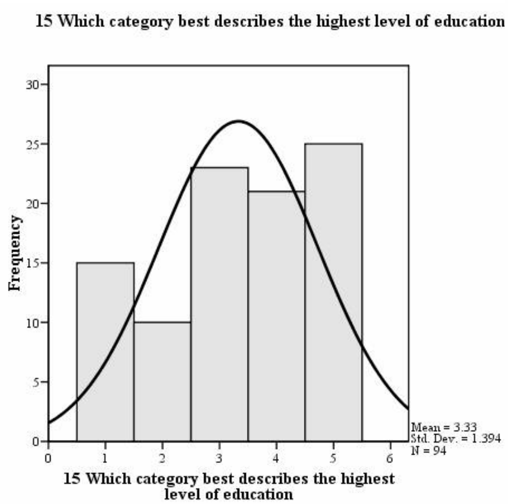
Response coding for question 13:
1 = Family 2 = Friends 3 = Co-workers 4 = Schoolmates or students
Response coding for question 14:
0 = No 1 = Yes

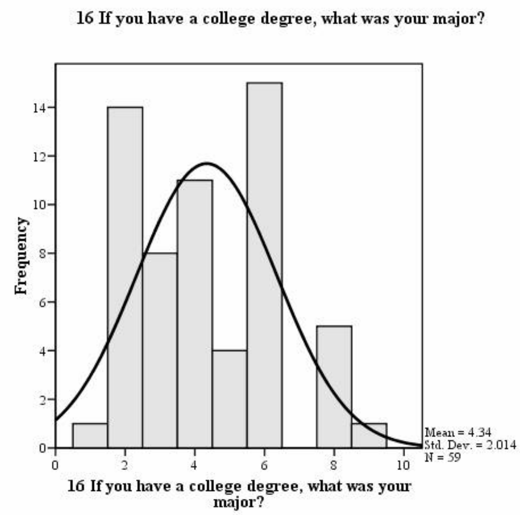
14a. If you answered yes, How many children did you come with?
14b. What is/are their ages? (circle all that apply)



Response coding for question 14a:
1 = 0 2 = 1 – 2 3 = 3 – 4 4 = 5 – 6 5 = 7 +
Response coding for question 14b:
1 = <1 to 2 2 = 3 - 5 3 = 6 - 8 4 = 9 - 11 5 = 12 – 14
6 = 15 – 17 7 = 18+

15. Which category best described the highest level of education you have completed?
16. If you have a college degree, what was your major?





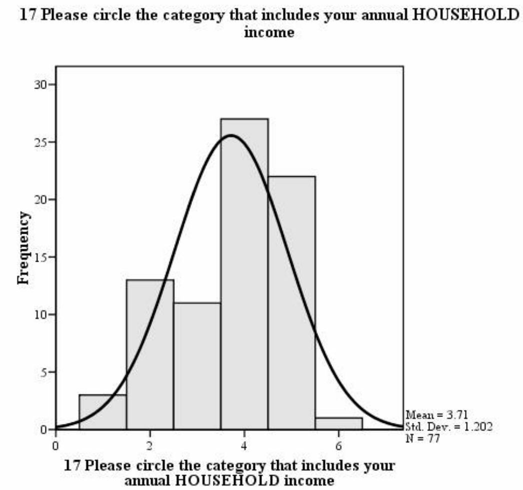
Response coding for question 15:

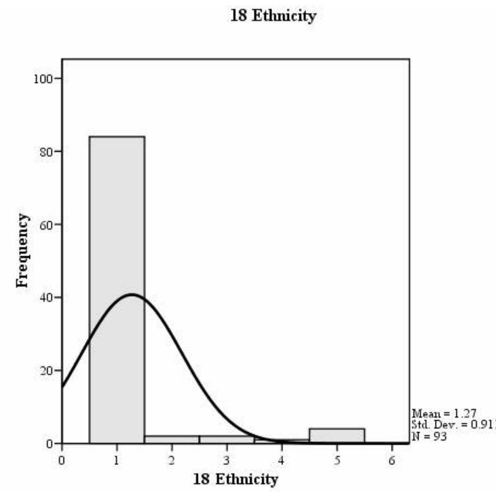
1 = elementary	2 = high school	3 = some college
4 = undergraduate degree	5 = advanced degree	

Response coding for question 16:

1 = fine/performing arts	2 = science and engineering	
3 = medical related	4 = education	5 = journalism
6 = liberal arts	7 = not sure	8 = no college experience

17. Please circle the category that includes your annual HOUSEHOLD income.
18. Race





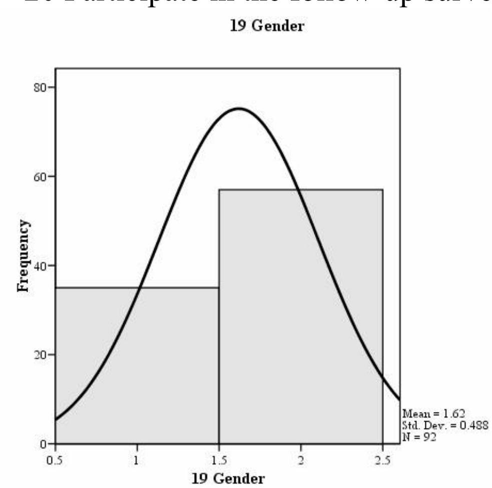
Response coding for question 17:

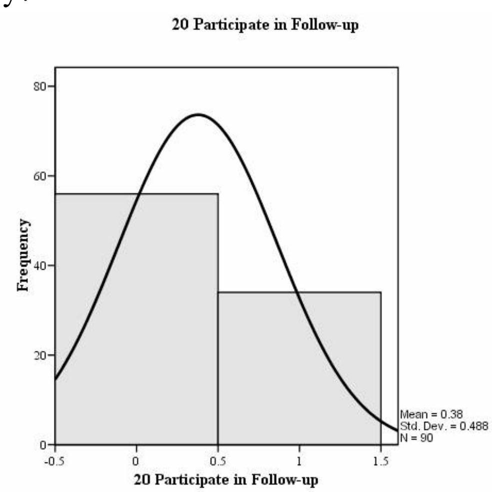
1 = less than $15,000 　　2 = $15,000 - $29,999
3 = $30,000 - $49,999 　　4 = $50,000 - $79,999
5 = over $75,000

Response coding for question 18:

1 = Caucasian 　　2 = African-American 　　3 = Asian
4 = Hispanic 　　5 = Other

19. Sex.
20 Participate in the follow-up survey?





Response coding for question 19:

1 = Male 　　2 = Female

Response coding for question 20:

0 = No 　　1 = Yes

Table: Percent Visitor Response to Manipulation Questions

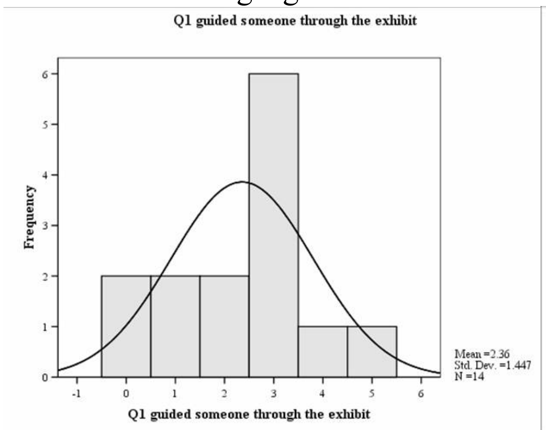
	N	Percentage				
		1 Not at all	2	3 Some	4	5 A lot
How much you manipulated the:						
Shuttle Approach Simulator	97	25.77	5.15	24.74	22.68	21.65
Mars Rover	96	32.29	13.54	22.92	21.88	9.38
Mars Soil Test	92	38.04	15.22	27.17	11.96	7.61
"Compatibility Test"	95	37.89	8.42	27.37	10.53	15.79
Robotic Arm	92	36.96	9.78	17.39	17.39	18.48
Astronaut Fitness Test	93	34.41	8.60	26.88	19.35	10.75
"Emergency Repairs"	91	35.16	12.09	14.29	28.57	9.89

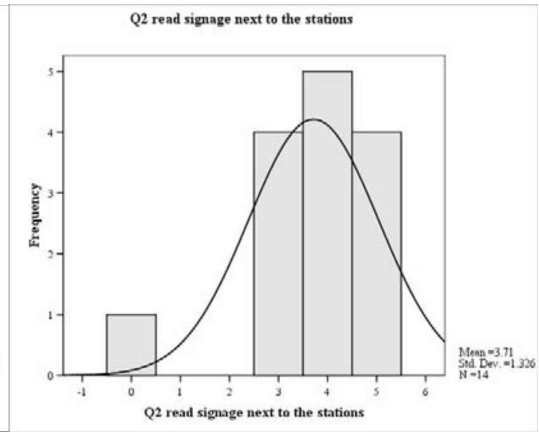
Appendix VIII: Follow-up Visitor Survey Frequency Data

A: Interaction

Please circle how much you:

1. Guided someone through the exhibit.
2. read signage next to the stations.



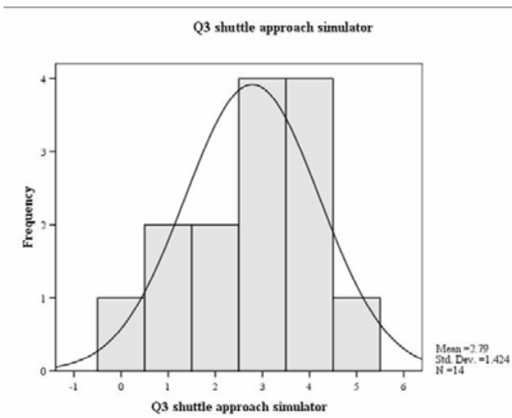


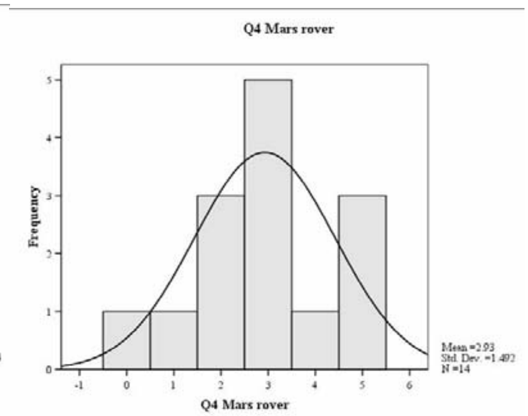
Response coding for question 1:

1 = Not at All; 2; 3 = Some; 4; 5 = A lot

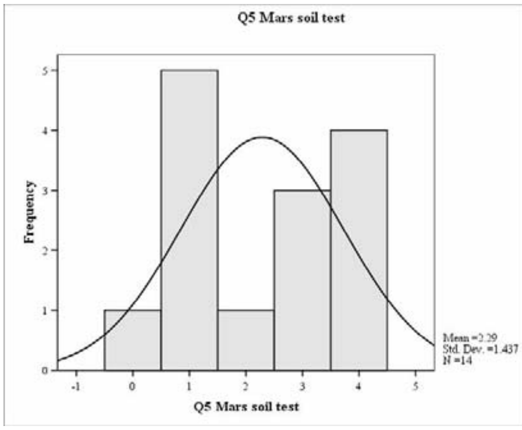
Manipulated the:

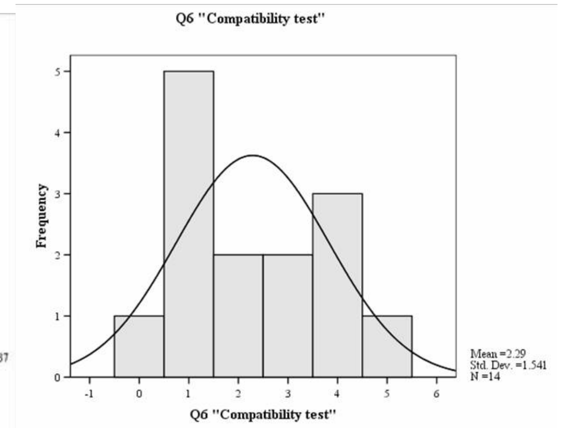
3. shuttle approach simulator
4. Mars rover.



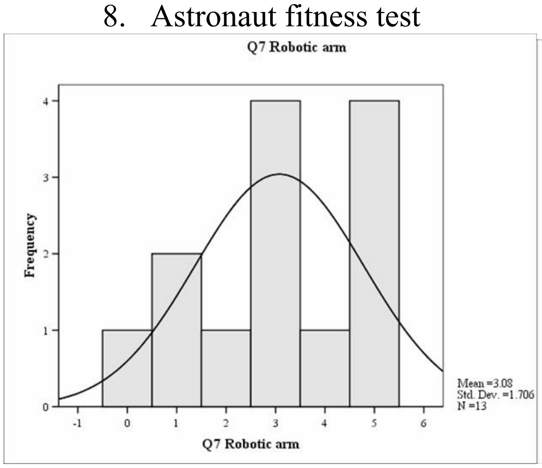


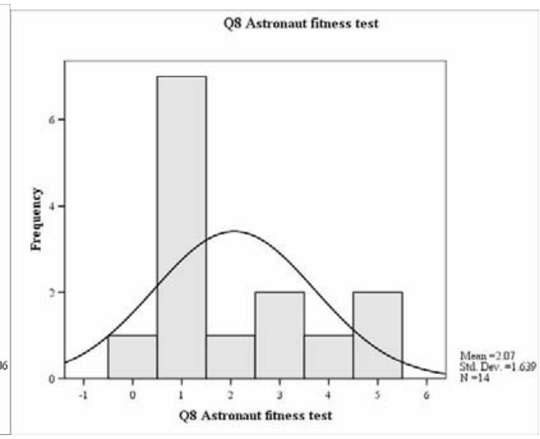
5. Mars soil test
6. “compatibility test” to center the Earth on the screen





7. robotic arm
8. Astronaut fitness test

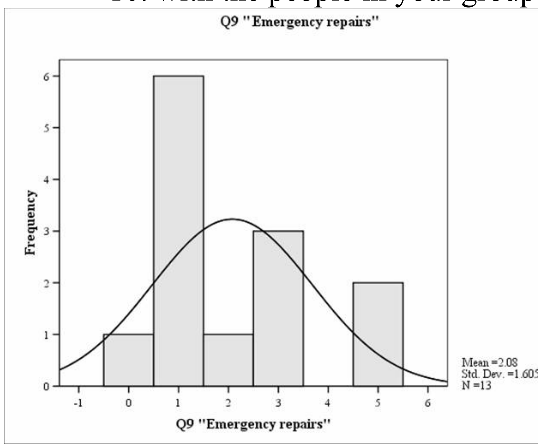


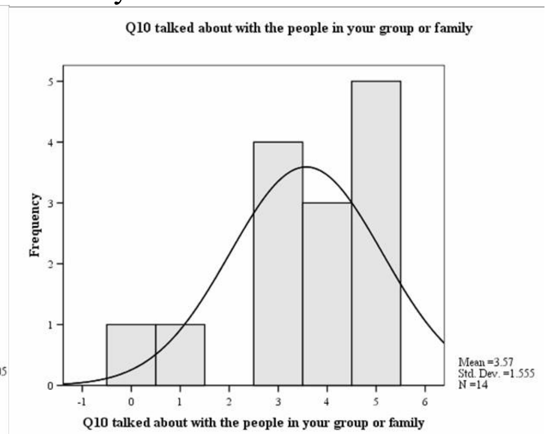


9. “emergency repairs” knobs

Talked about the exhibit:

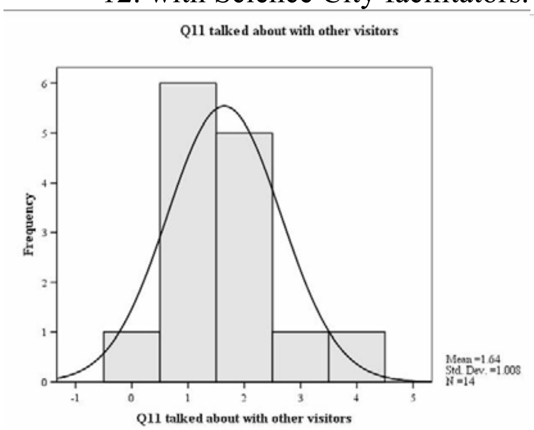
10. with the people in your group or family.

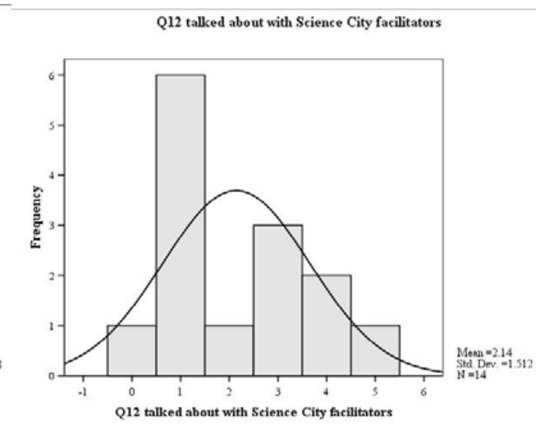




11. with other visitors.

12. with Science City facilitators.

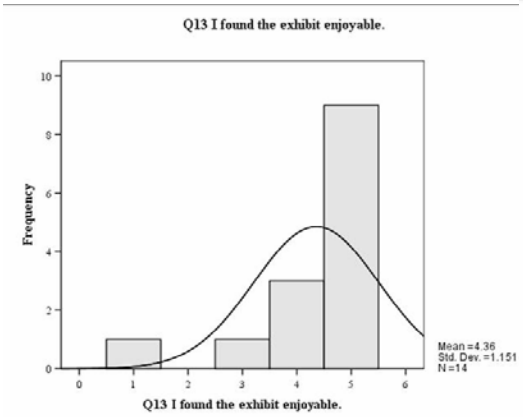


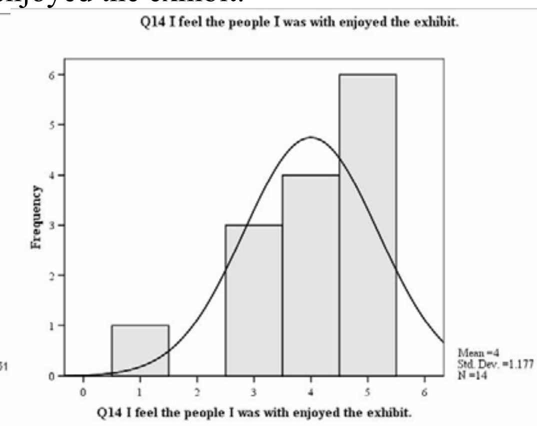


B. Visitor Attitude

Based on your experience, please indicate your level of agreement.

13. I found the exhibit enjoyable.
14. I feel the people I was with enjoyed the exhibit.

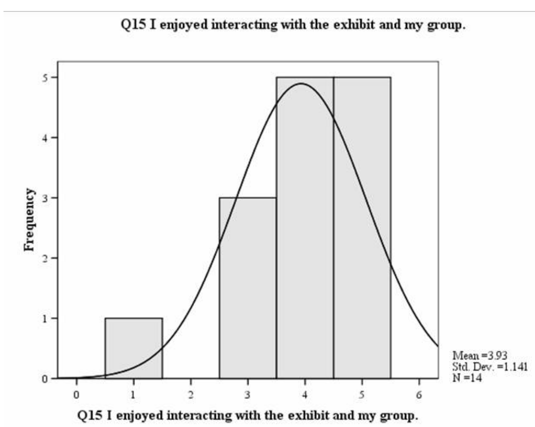


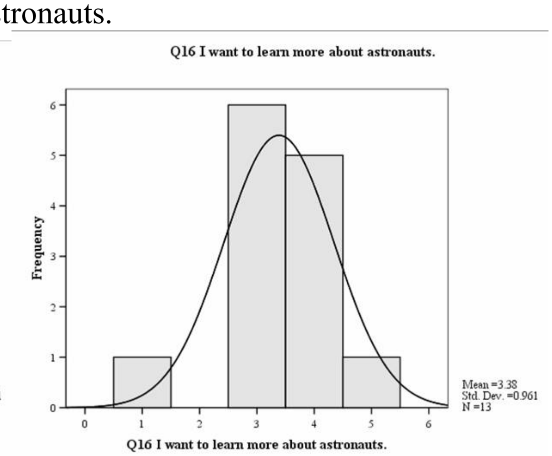


Response coding for question 1:

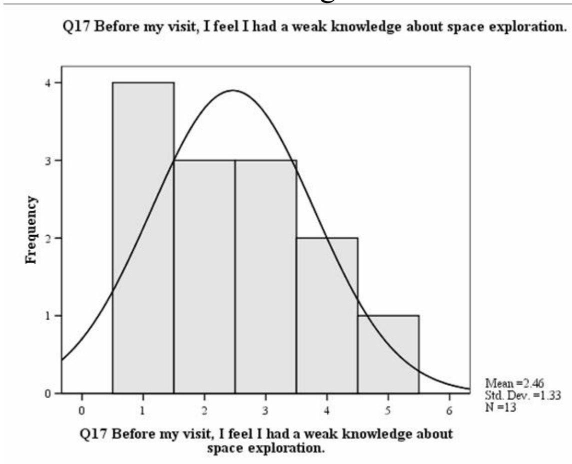
1 = Mostly disagree; 2; 3 = Neutral; 4; 5 = Mostly agree

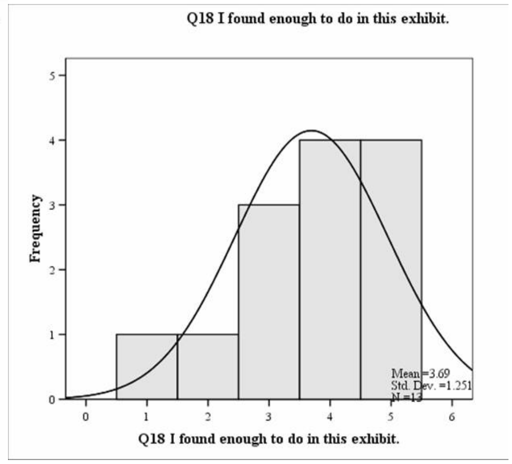
15. I enjoyed interacting with the exhibit and my group.
16. I want to learn more about astronauts.





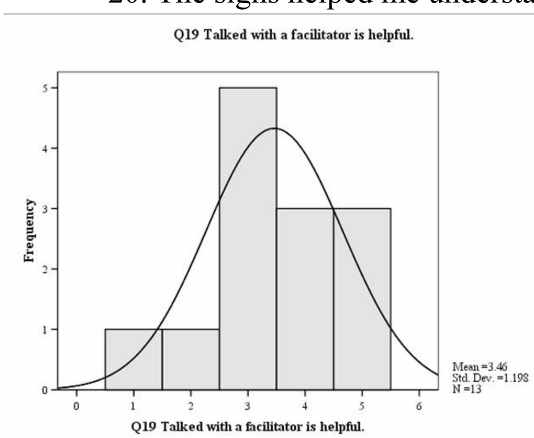
17. Before my visit, I feel I had a weak knowledge about space exploration.
18. I found enough to do in this exhibit.

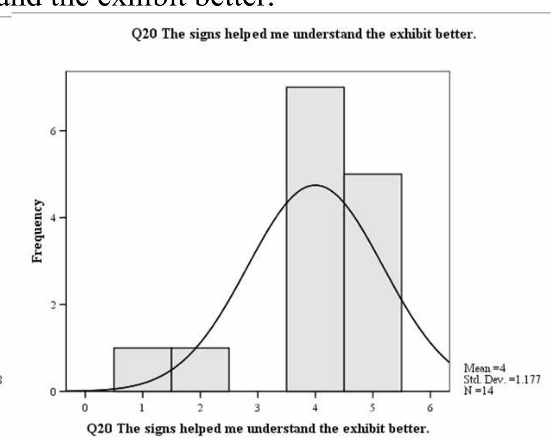




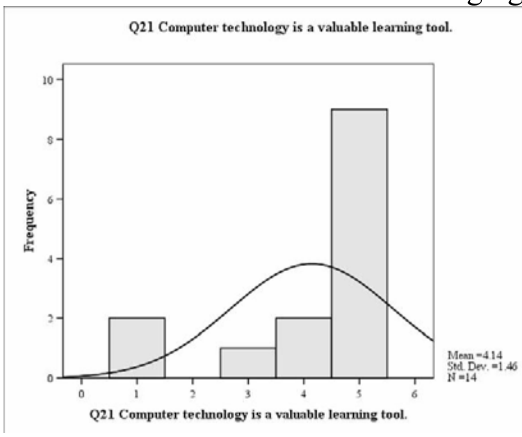
s

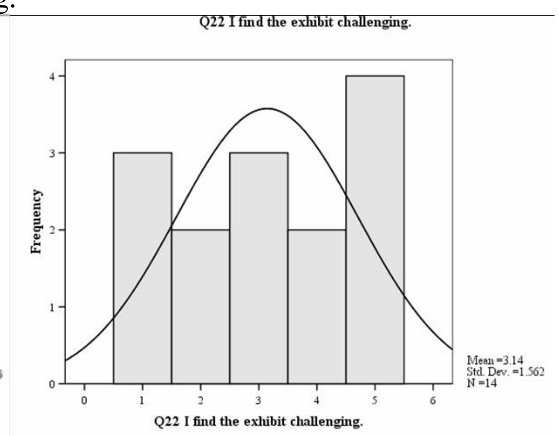
19. Talking with a facilitator is helpful.
20. The signs helped me understand the exhibit better.



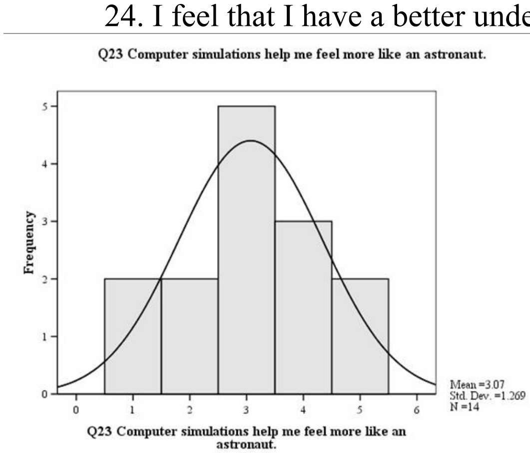


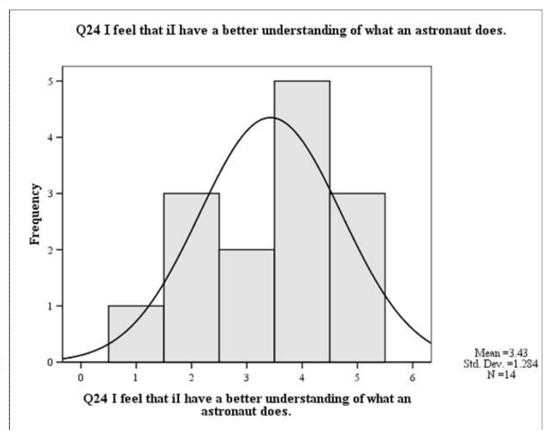
21. Computer technology is a valuable learning tool.
22. I find the exhibit challenging.



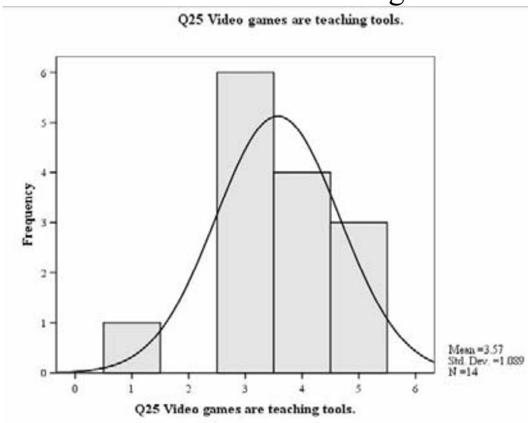


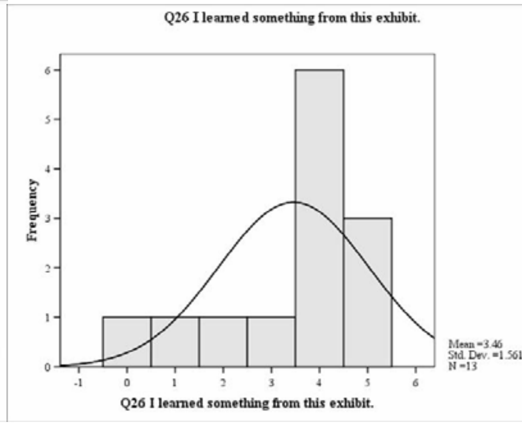
23. Computer simulations help me feel more like an astronaut.
24. I feel that I have a better understanding of what an astronaut does.



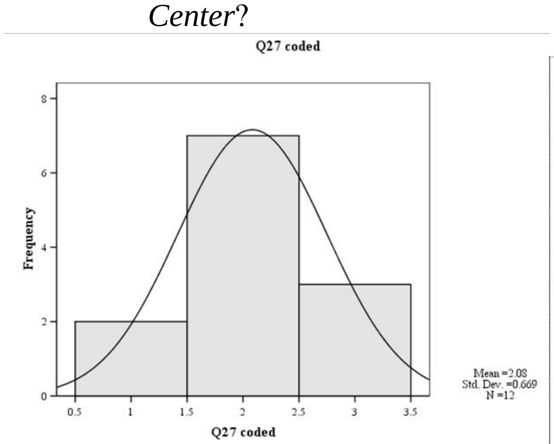


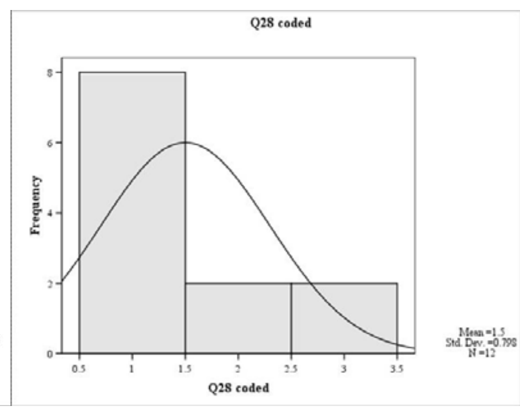
25. I learned something from this exhibit.
26. I learned something from this exhibit.





27. Describe what you feel you learned from the exhibit.
28. What do you remember most about your visit to the *Astronaut Training Center*?

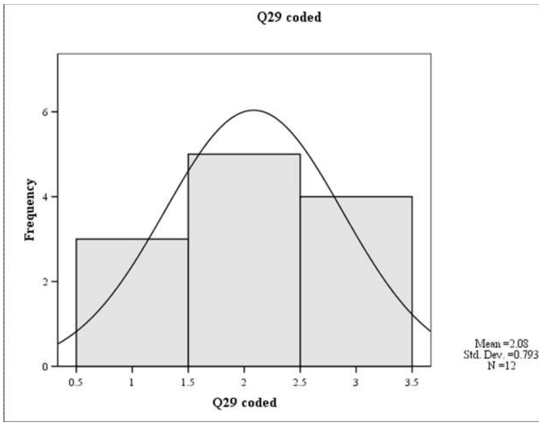


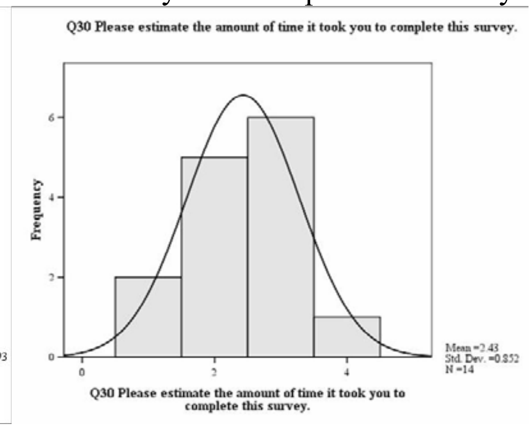


Response coding for question 27, 28, and 29:

1 = Identifying   2 = Describing   3 = Interpreting and Applying

29. What would make this exhibit more meaningful to you?
30. Please estimate the amount of time it took you to complete this survey.





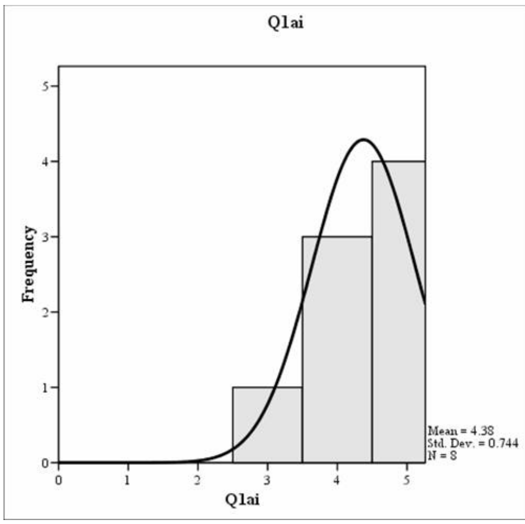
Response coding for question 30:

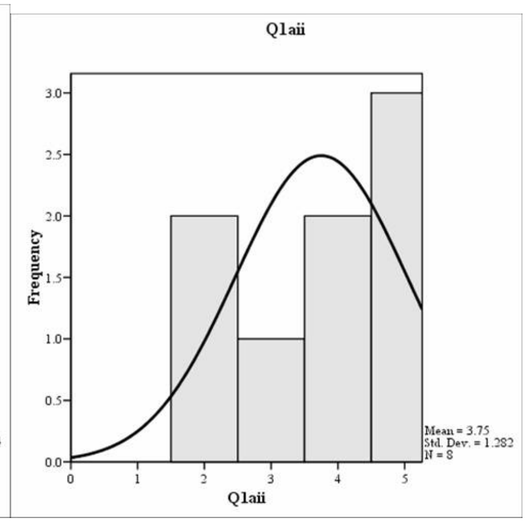
1 = 1 – 5 minutes 2 = 5 – 10 minutes 3 = 11 – 15 minutes
4 = 15 + minutes

Appendix IX: Facilitator Survey Frequency Data

A. Interaction:

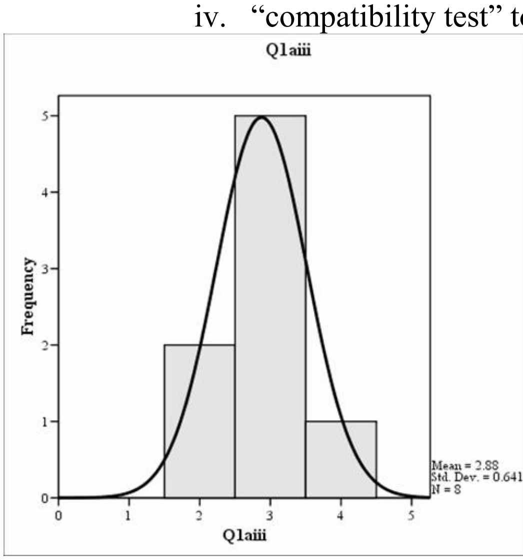
1. Do you feel visitors:
    a. manipulate:
        i. shuttle approach simulator
        ii. Mars rover

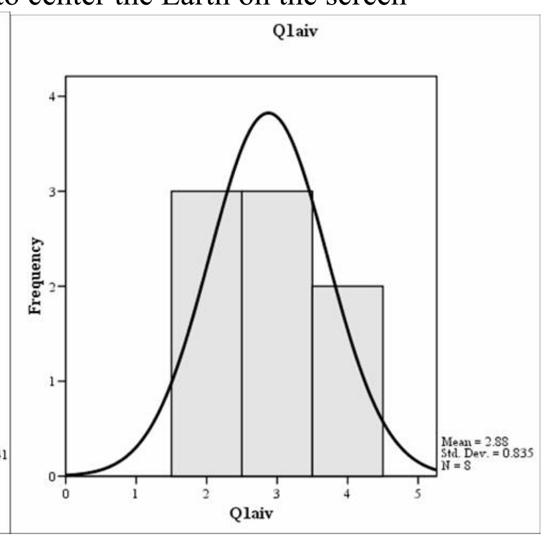




Response coding for question 1:
1 = Not at all; 2; 3 = Some; 4; 5 = A lot

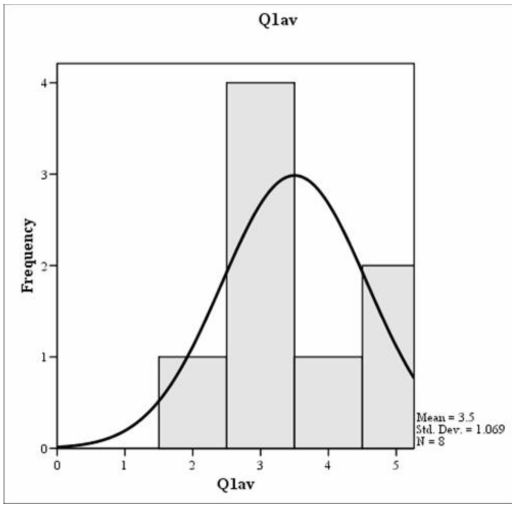
iii. Mars soil test
iv. "compatibility test" to center the Earth on the screen

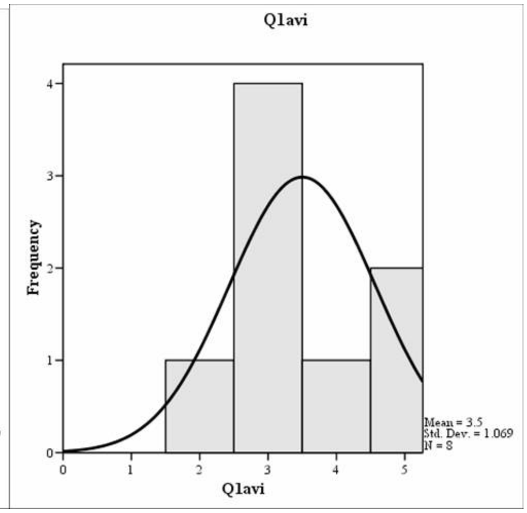




v. robotic arm

vi. Astronaut fitness test

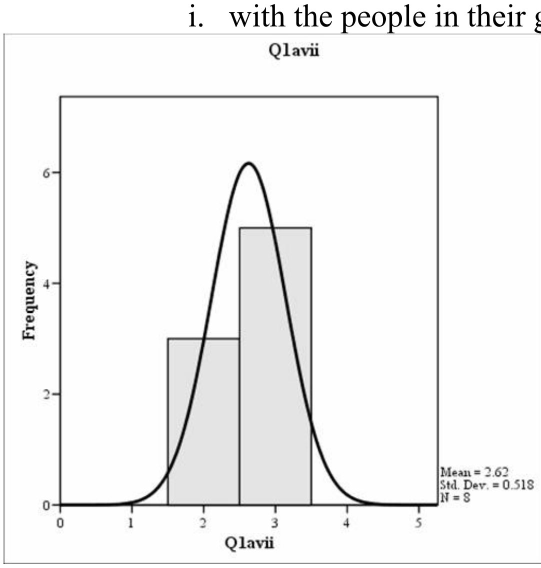


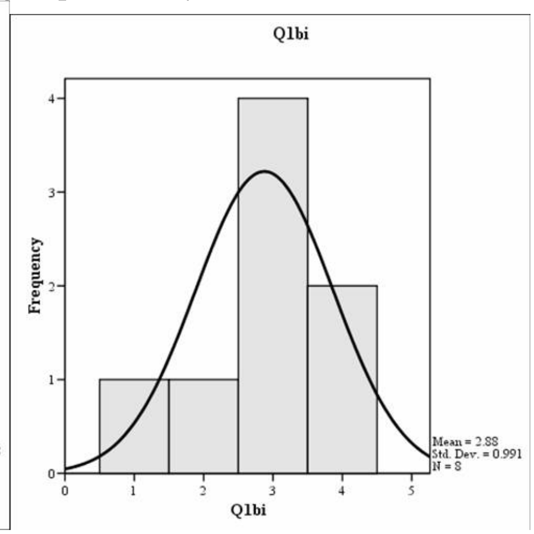


vii. "emergency repairs" knobs

b. talked about the exhibit:

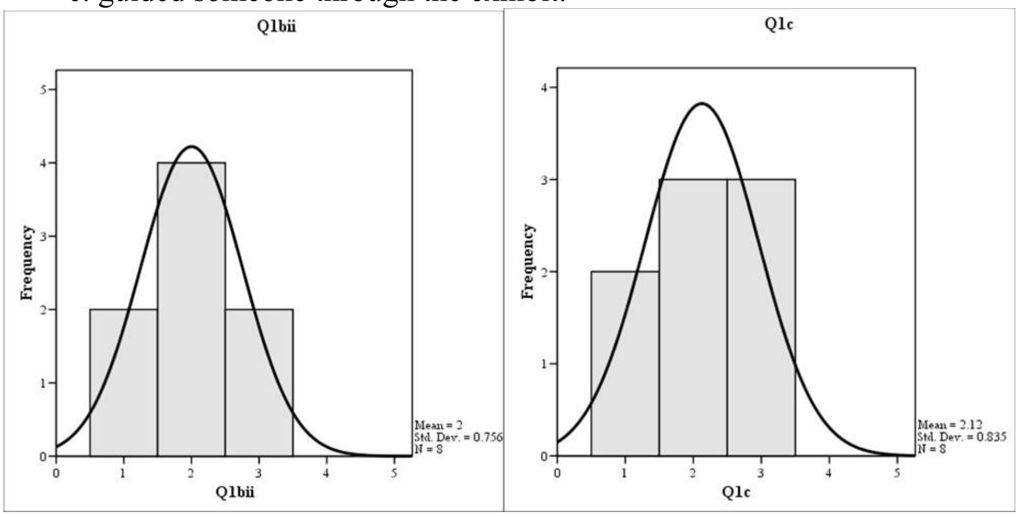
i. with the people in their group or family.





ii. with other visitors.

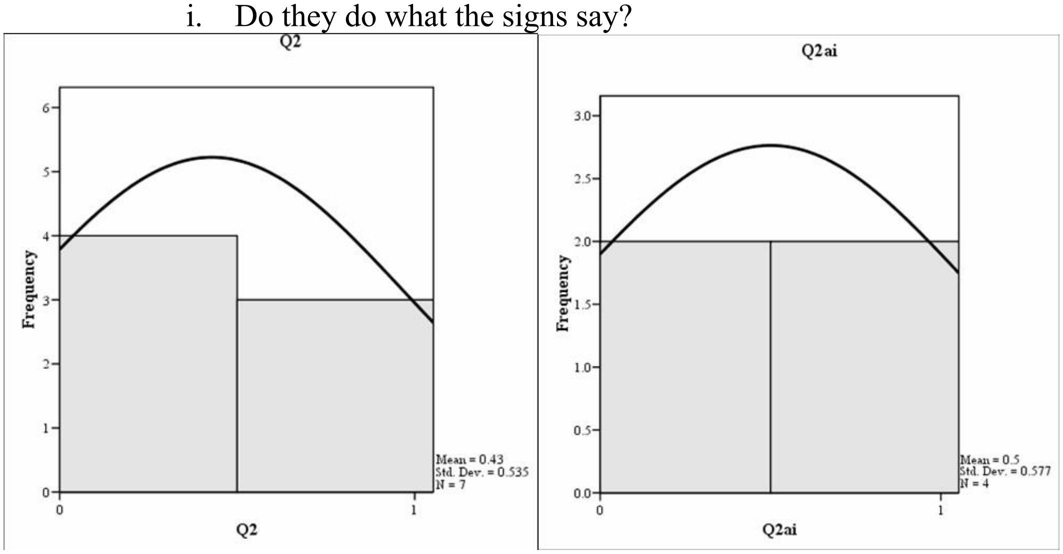
c. guided someone through the exhibit.



2. Do visitors read the signs next to the stations?

a. If you answered yes:

i. Do they do what the signs say?

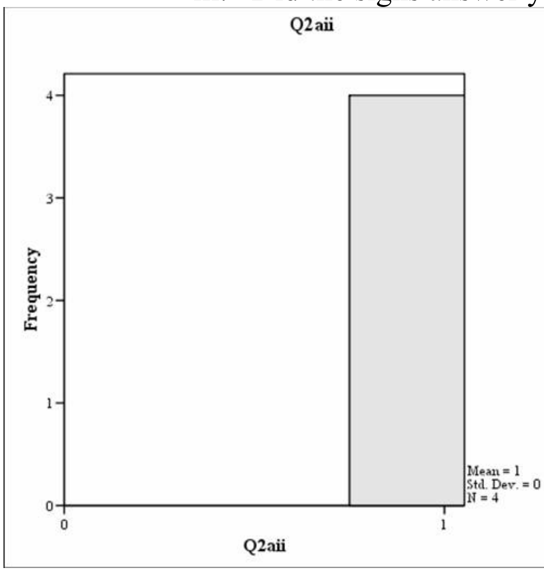


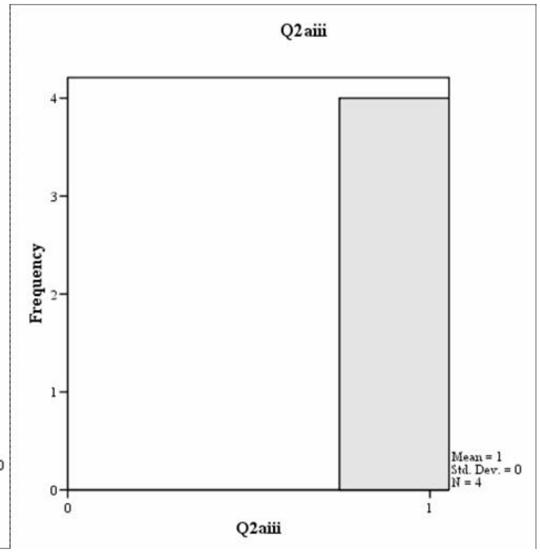
Response coding for question 2:

0 = No 1 = Yes

ii. Do you think the signs are helpful when playing with the exhibit?

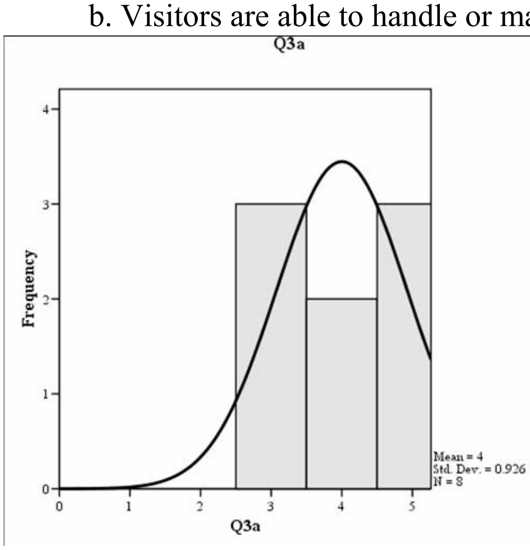
iii. Did the signs answer your questions about this exhibit?

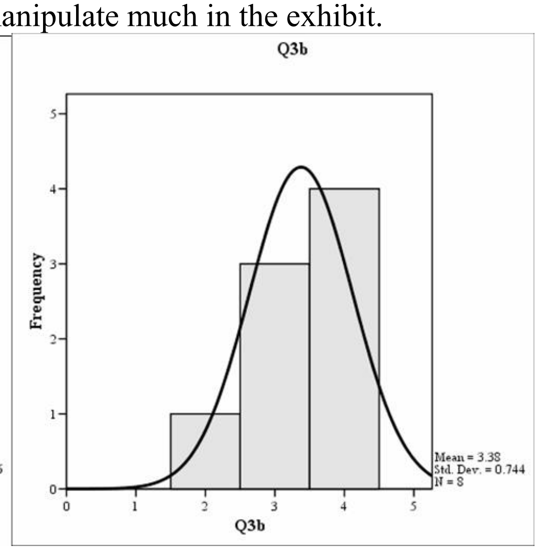




B. Staff Attitude

3. Please indicate your level of agreement:
   a. I feel the exhibit adds to visitors' understanding of an astronaut's experiences.
   b. Visitors are able to handle or manipulate much in the exhibit.

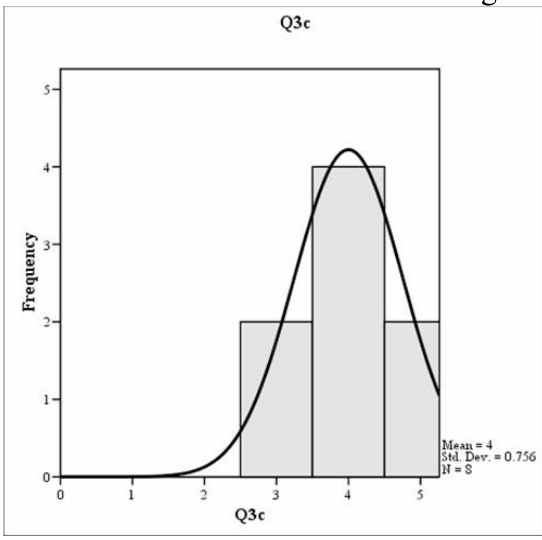


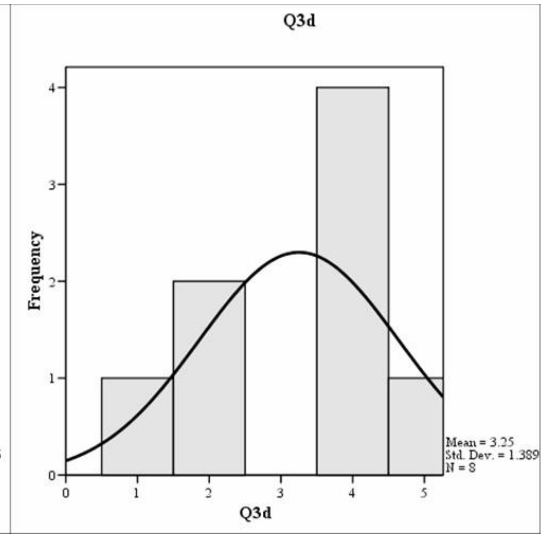


Response coding for question 3 and 4:

1 = Mostly disagree; 2; 3 = Neutral; 4; 5 = Mostly agree

c. Reading the labels is useful to understanding the exhibit.
d. Visitors can learn something about Mars from the exhibit.

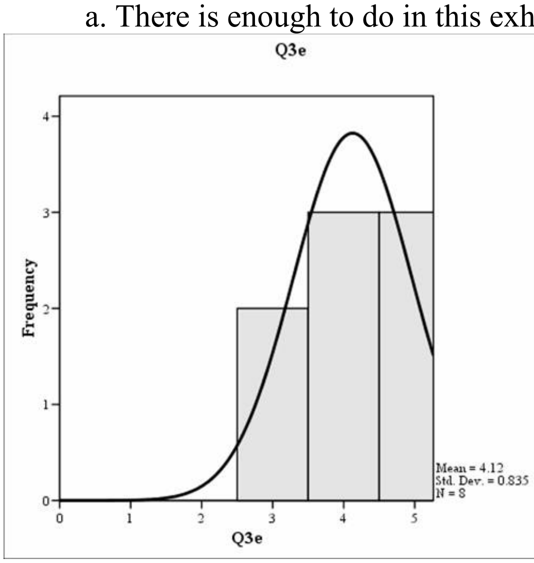


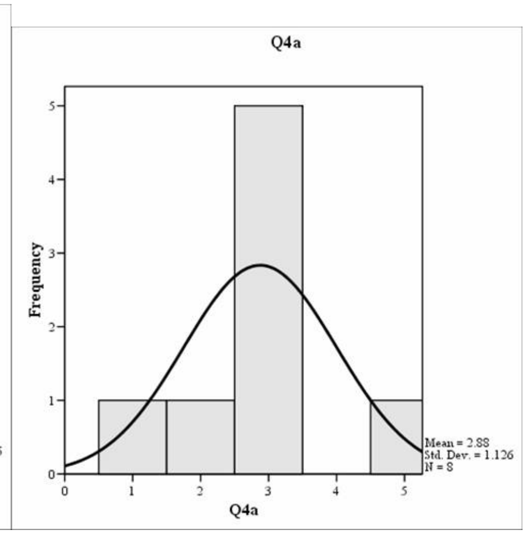


e. I feel the Living Quarters exhibit could be more detailed.

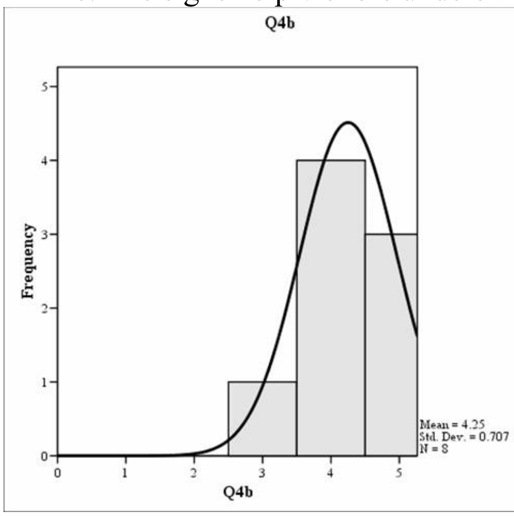
4. Based on your experience, please indicate your level of agreement:

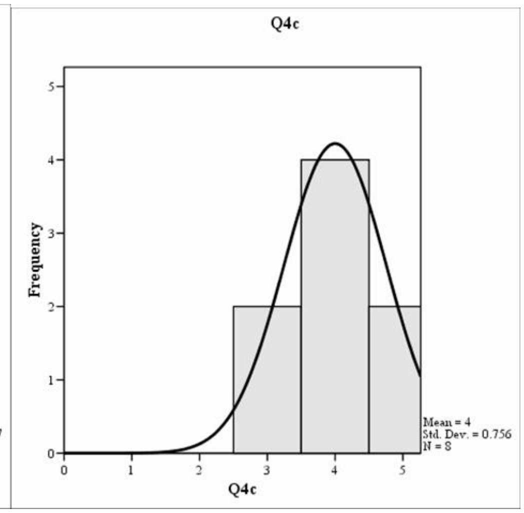
a. There is enough to do in this exhibit.



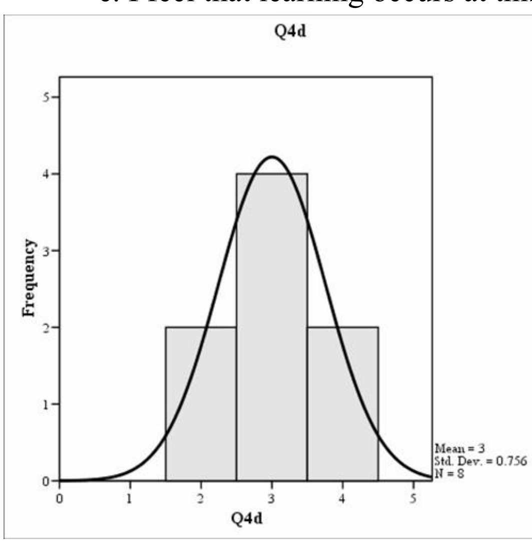


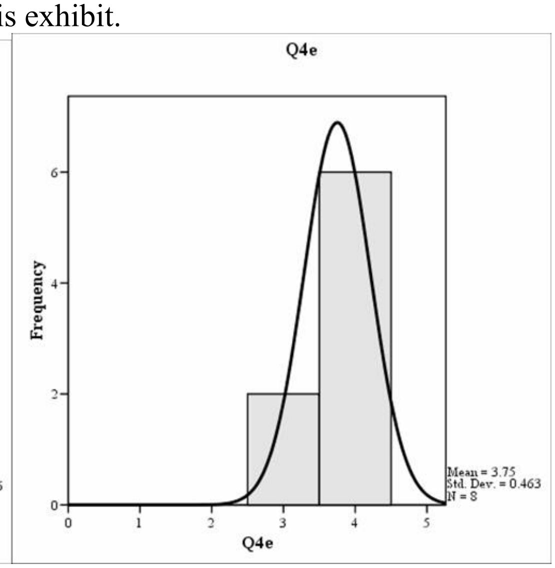
b. Talking with a facilitator is helpful.
c. The signs help visitors understand the exhibit better.





d. Visitors need more information to understand the exhibit.
e. I feel that learning occurs at this exhibit.

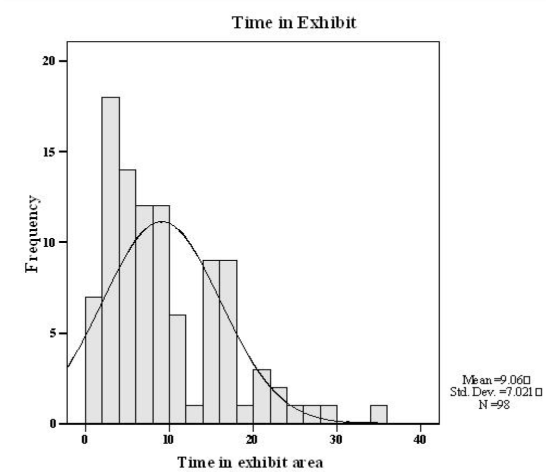


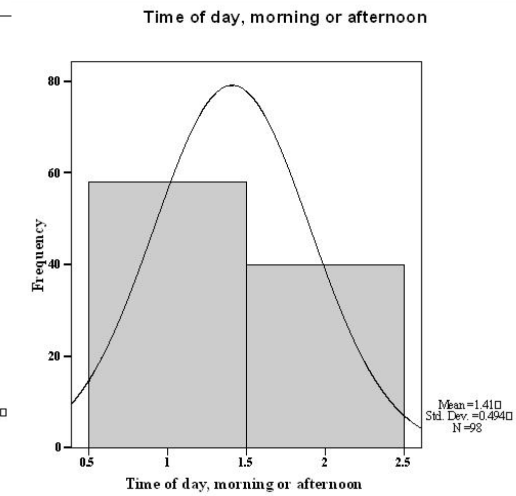


Appendix X: Behavior Analysis Frequency Data

Demographics:

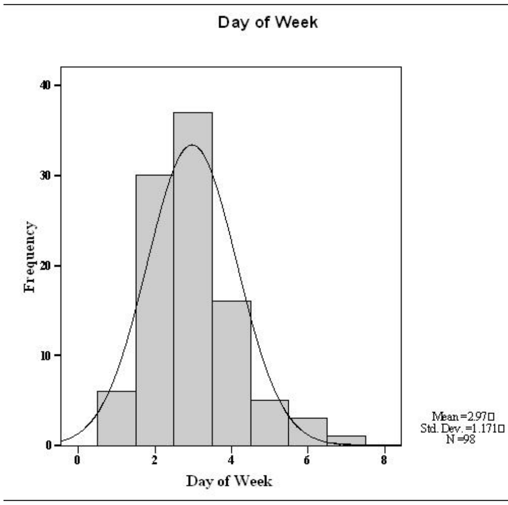
1. Length of time
2. Time of day

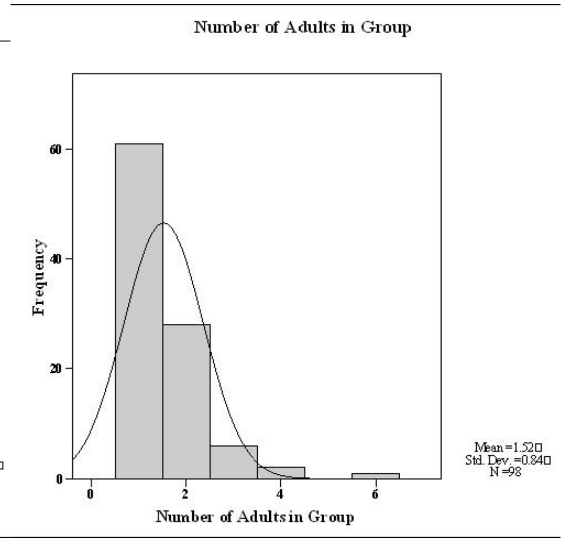




Number of minutes in exhibit
Time of day: 1 = morning, 2 = afternoon

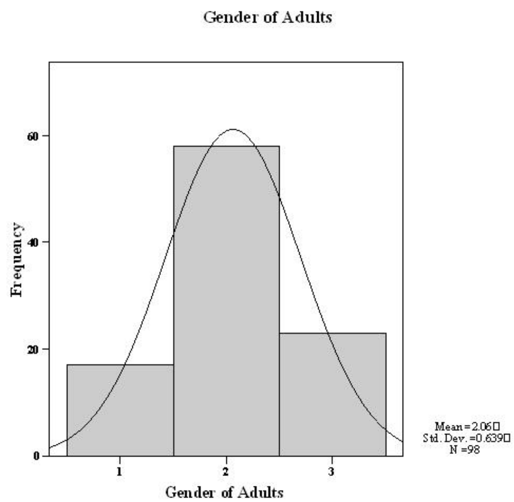
3. Day of the week
4. Number of adults in the group

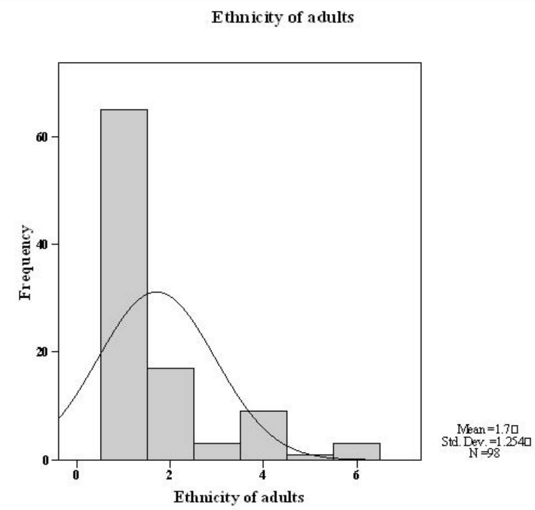




Day of week: 1 = Wednesday, 2 = Thursday, 3 = Friday, 4 = Saturday, 5 = Sunday, 6 = Monday, 7 = Tuesday

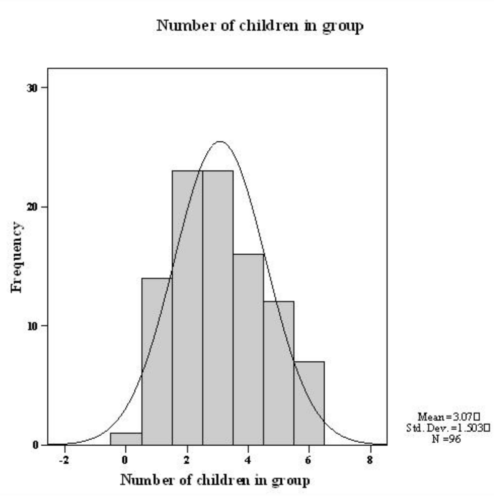
5. Gender of adults
6. Ethnicity of adults

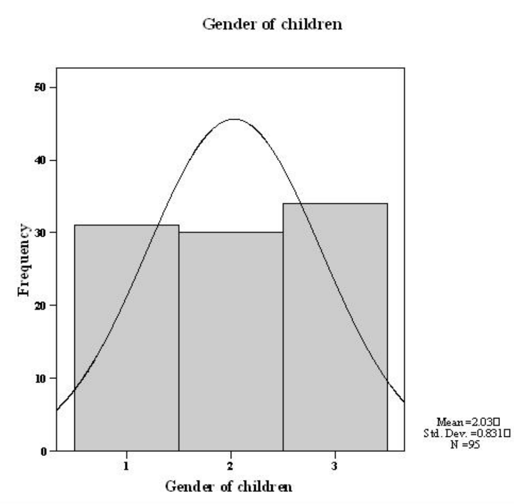




Gender: 1 = all male, 2 = all female, 3 = mixed group
Ethnicity:1 = white, 2 = black, 3 = Asian, 4 = Hispanic, 5 = Other, 6 = Mixed group

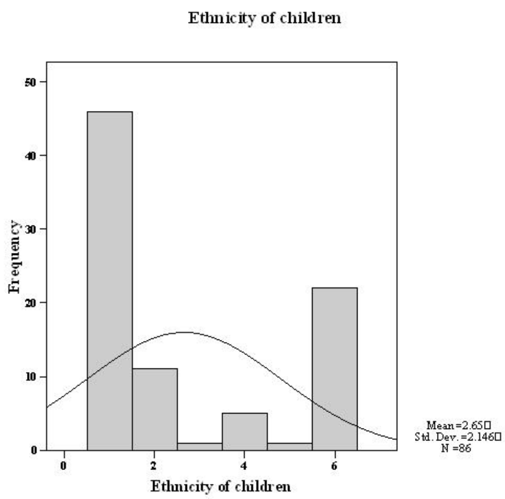
7. Number of Children in the group
8. Gender of children

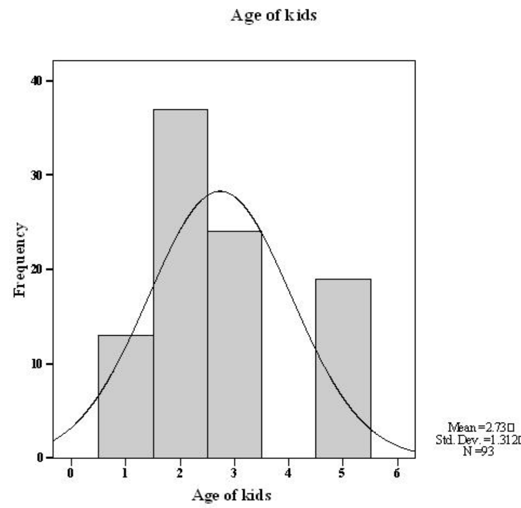




Gender: 1 = all male, 2 = all female, 3 = mixed group

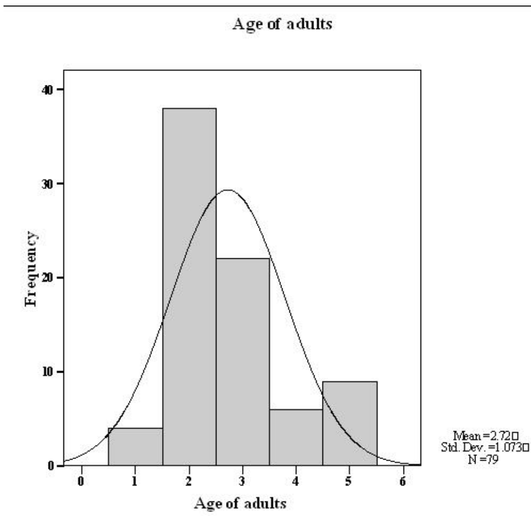
9. Ethnicity of children:
10. Age of kids:

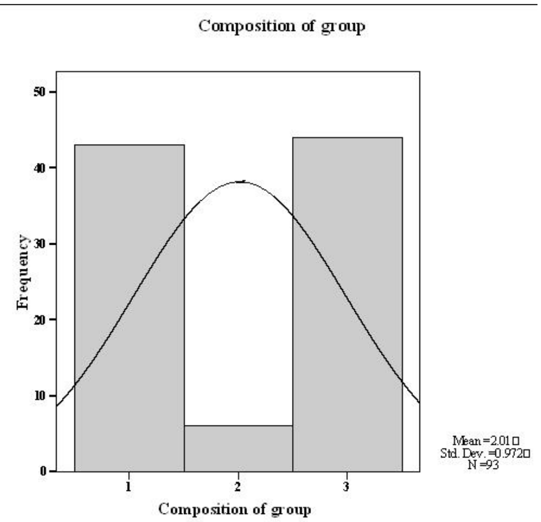




Ethnicity:1 = white, 2 = black, 3 = Asian, 4 = Hispanic, 5 = Other, 6 = Mixed group
Age of children: 1 = 1-5, 2 = 6-10, 3 = 11-15, 4 = 16-18, 5 = multiple ages

11. Age of adults:
12. Composition of group:

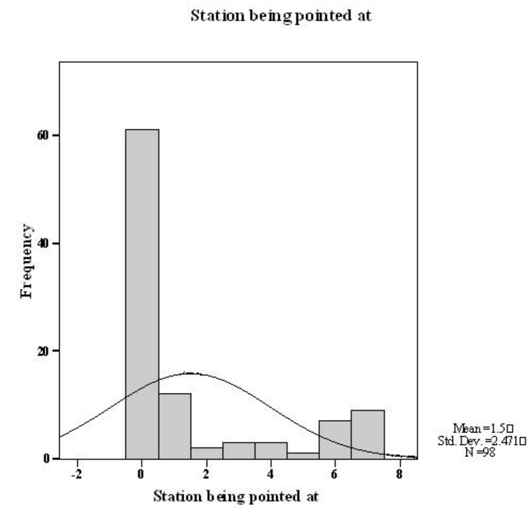


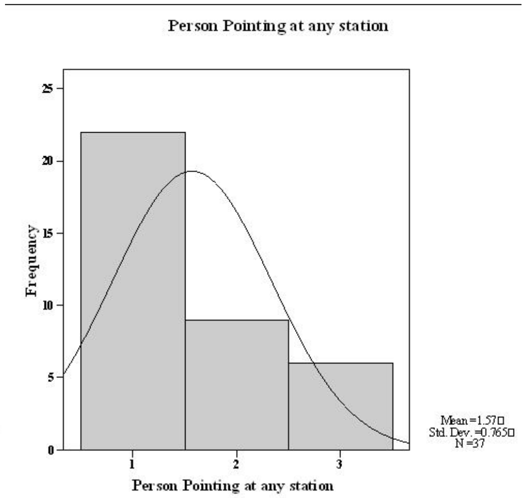


Age of adults: 0 = no response, 1 = 19-30, 2 = 31-40, 3 = 41-50, 4 = 50+, 5 = multiple ages
Composition of group: 1 = Family, 2 = Friends, 3 = School

A. Behaviors

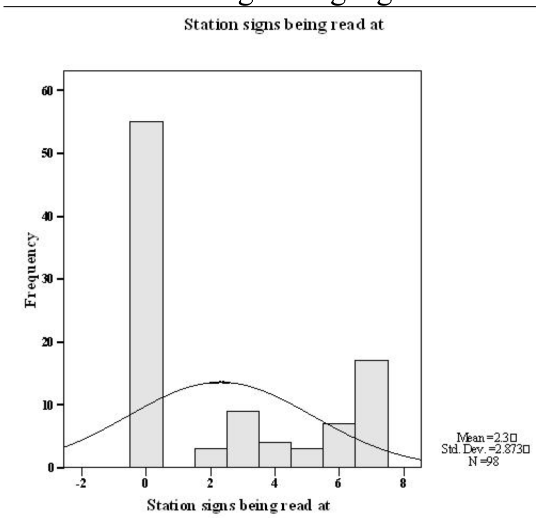
13. Station individual is pointing at
14. Person pointing at a station

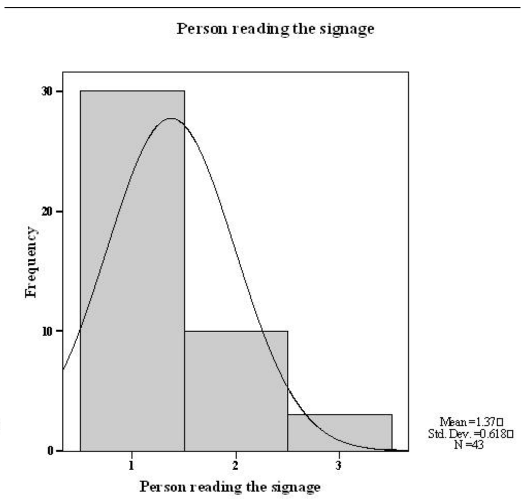




Station: 0 = no pointing, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.
Person: 1 = adult, 2 = child, 3 = both adults and children

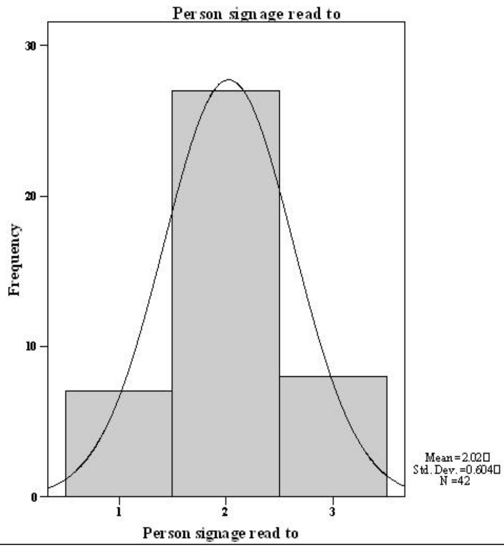
15. Station signs being read at:
16. Person reading the signage

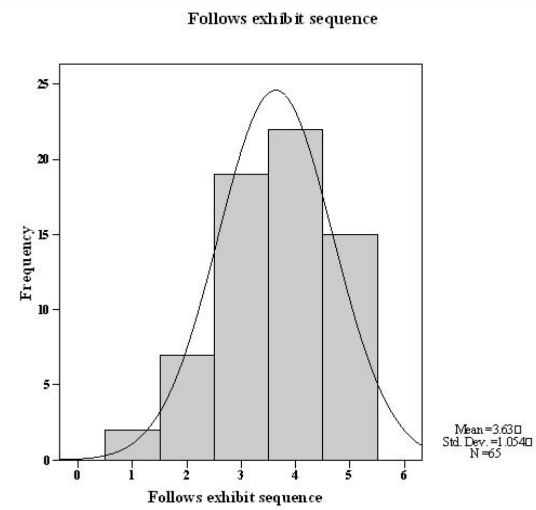




Station: 0 = no reading seen, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.
Person: 1 = adult, 2 = child, 3 = both adults and children

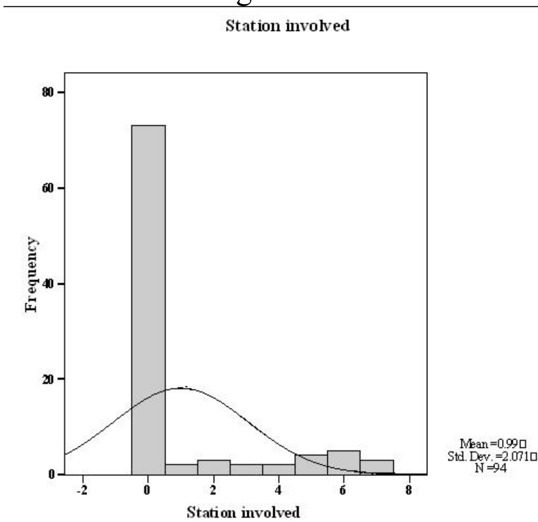
17. Person signage read to:
18. Follows exhibit sequence:

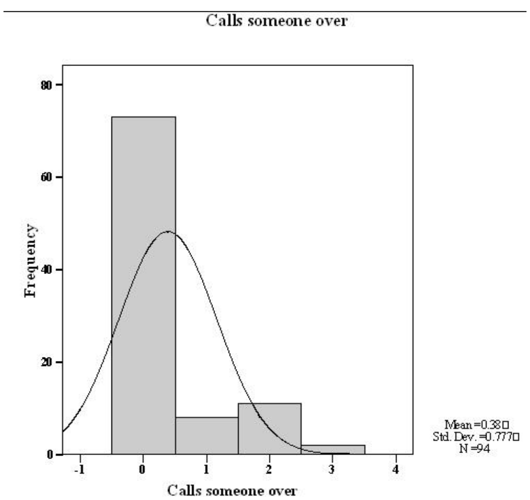




Person: 1 = adult, 2 = child, 3 = both adults and children
Sequence rating: 1 = never, 2 = rarely, 3 = some, 4 = frequently, 5 = very frequently

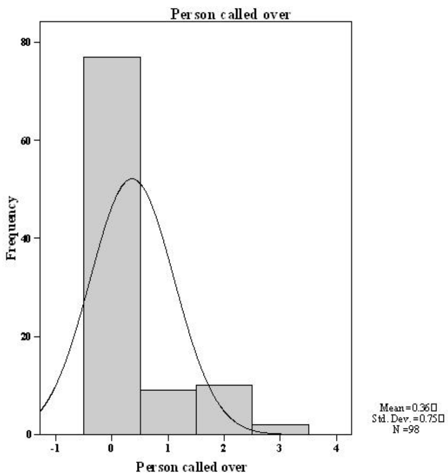
B. Conversation:
19. Station being talked about:
20. Person calling someone over:

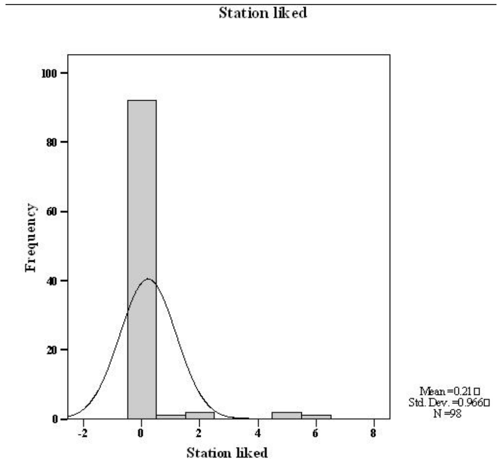




Station: 0 = no comment, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.
Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

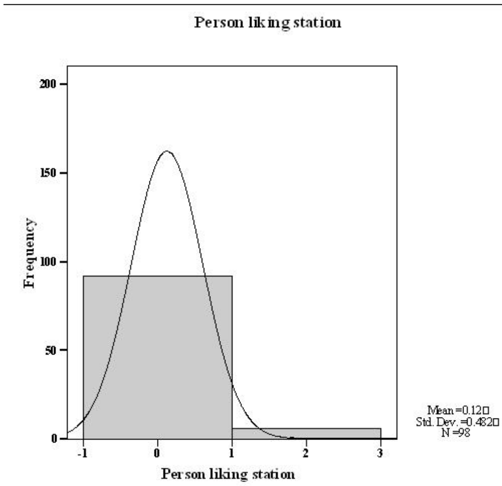
21. Person called over:
22. Station liked:

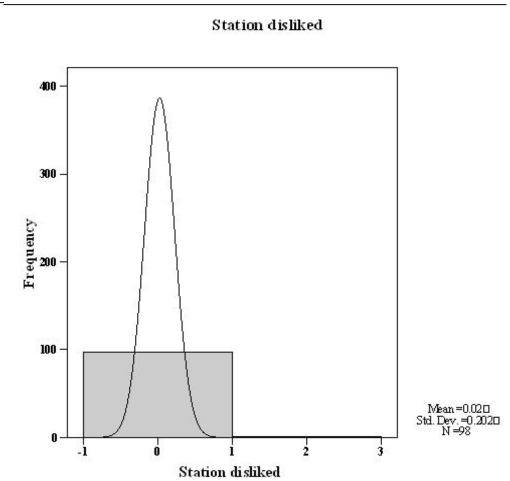




Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children
Station: 0 = no comment, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.

23. Person liking the station:
24. Station disliked:

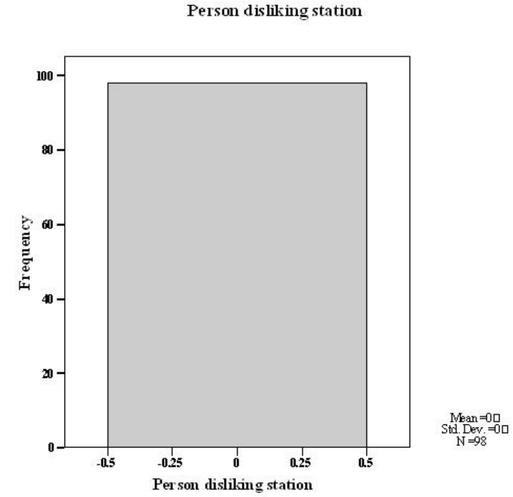


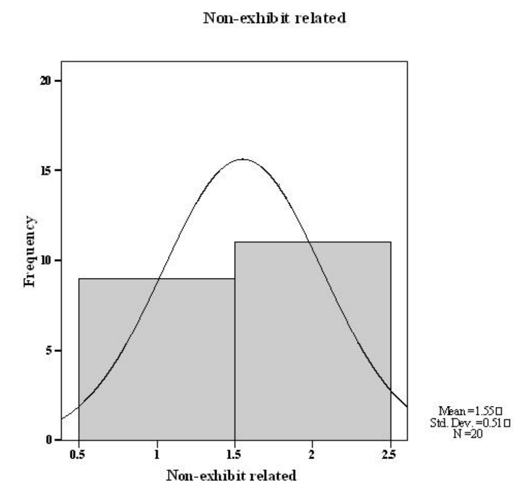


Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children
Station: 0 = no comment, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.

25. Person disliking the station:

26. Non-exhibit related conversation by a person:

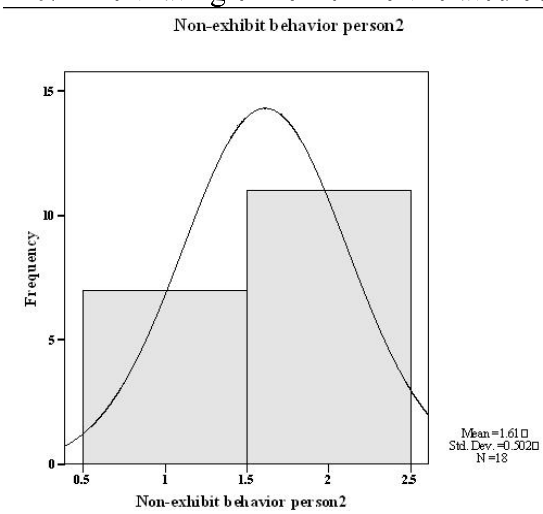


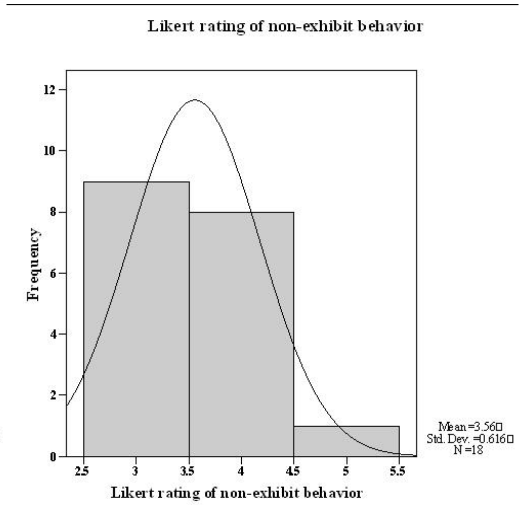


Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

27. Non-exhibit related conversation to a person:

28. Likert rating of non-exhibit related behavior:





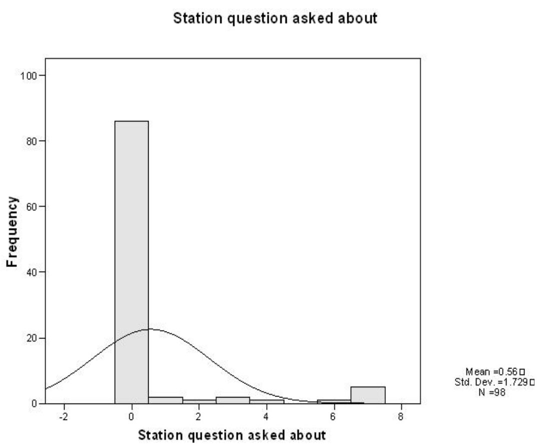
Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

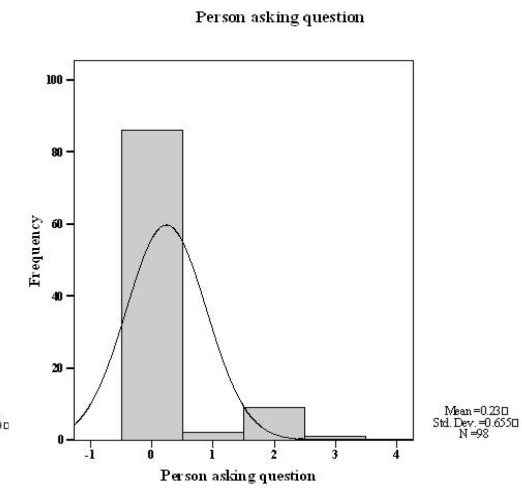
Sequence rating: 1 = never, 2 = rarely, 3 = some, 4 = frequently, 5 = very frequently

C. Interaction:

29. Asks questions about an exhibit:

30. Person asking a question::





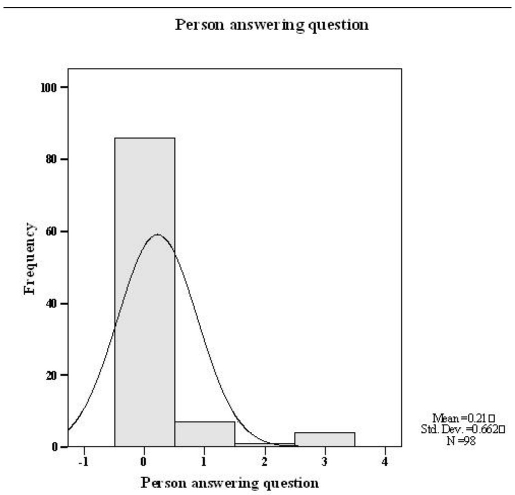
Station: 0 = no interaction, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.

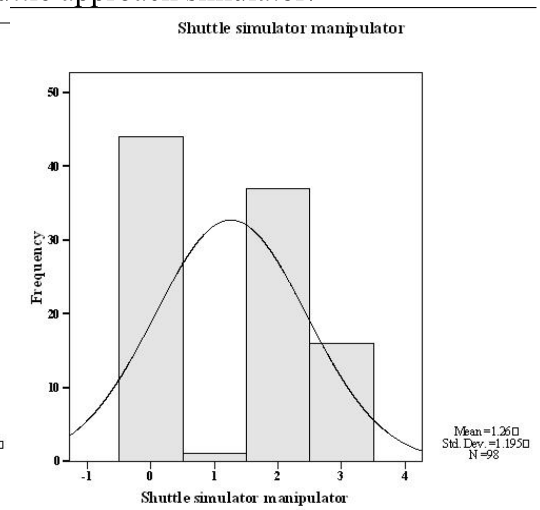
Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

31. Person answering the question:

Manipulation of exhibits

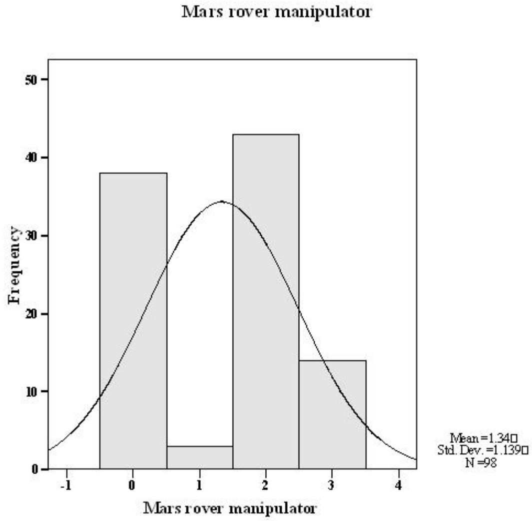
32. Age of person manipulating the shuttle approach simulator:

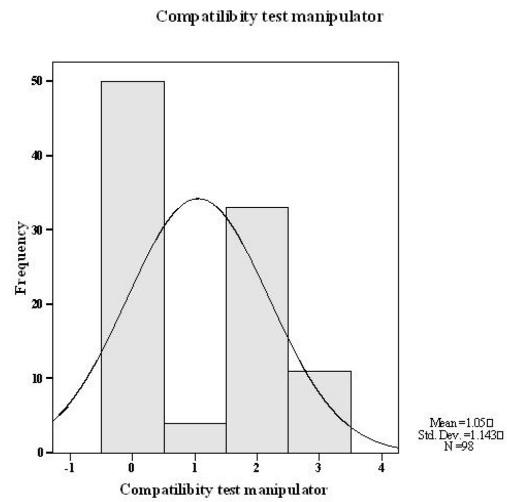




Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

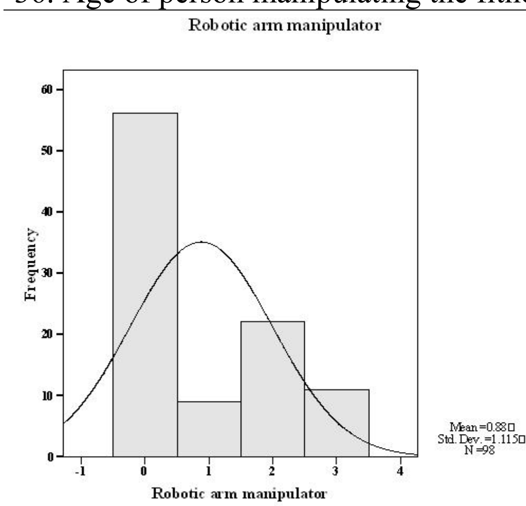
33. Age of person manipulating the Mars rover manipulator:
34. Age of person manipulating the compatibility test:

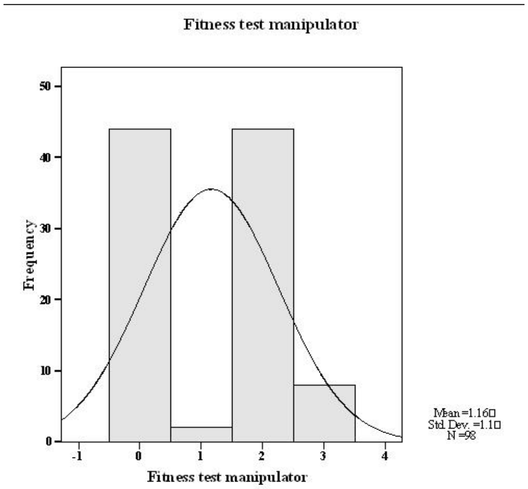




Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

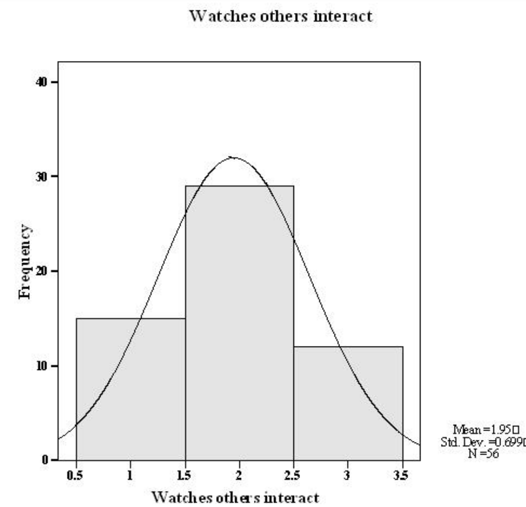
35. Age of person manipulating the Robotic arm:
36. Age of person manipulating the fitness test:





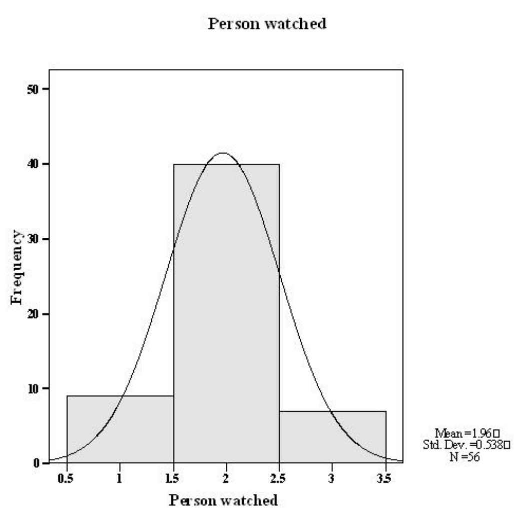
Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

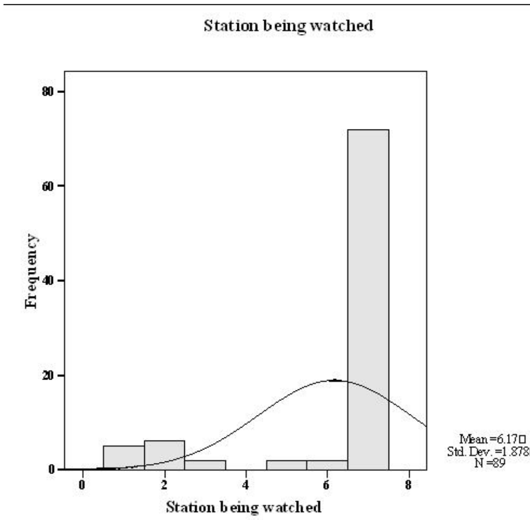
37. Age of person manipulating the dizziness challenge:
38. Watches others interact:



Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children

39. Person being watched:
40. Station being watched:





Person: 0 = no one involved, 1 = adult, 2 = child, 3 = both adults and children
Station: 0 = no interaction, 1 = shuttle simulator, 2 = Mars rover, 3 = compatibility test/make repairs, 4 = Robotic arm, 5 = fitness test, 6 = dizziness challenge, 7 = multiple stations pointed at.